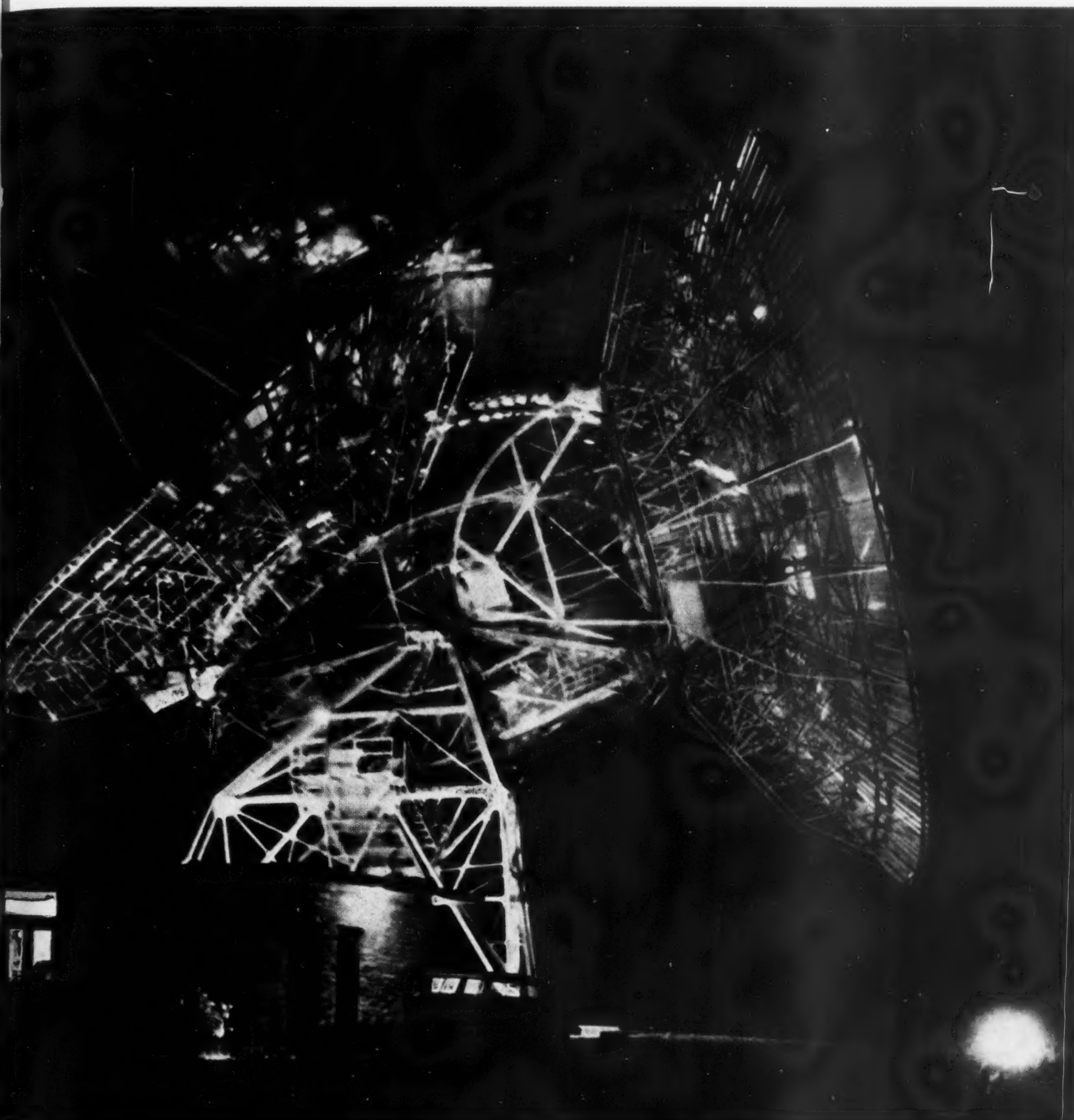
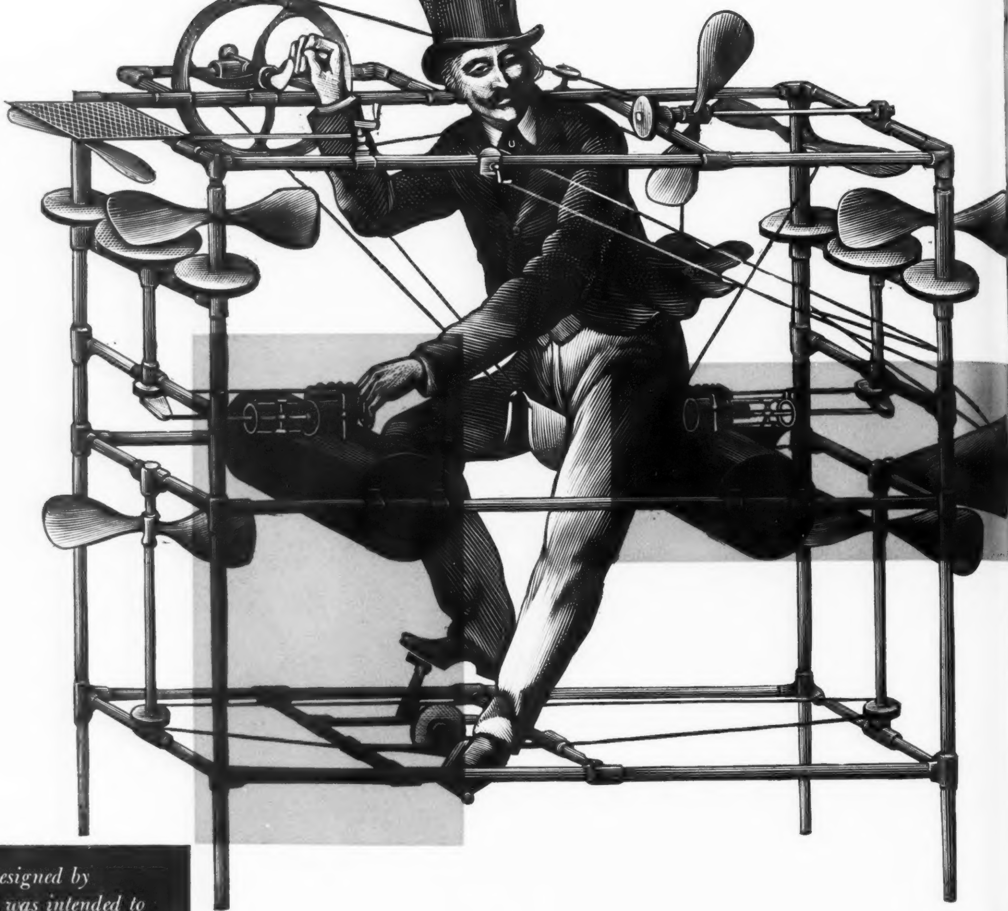
Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY
MARCH 1960





Ayres' Aerial Machine, designed by Dr. W. O. Ayres in 1885, was intended to get off the ground through compressed air generated by foot power. In this illustration of the machine, Brussel-Smith, noted graphic artist, has used his unique wood engraving technique to depict for this advertisement another of man's efforts to find the power necessary for sustained flight.

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March 1960 volume 5 number 3

EDITORIAL

FEATURES

INTERNATIONAL NEWS

RADIO ASTRONOMY

DEPARTMENTS

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Astro notes

NASA OUTLOOK

• Eight satellites and four deep-space probes are scheduled this year by the National Aeronautics and Space Administration, including one and possibly two more moon shots with Atlas-Able to make up for the failure of Thanksgiving Day, 1959. In 1961, according to NASA Administrator T. Keith Glennan, the civilian space agency will tackle a "sophisticated" lunar impact vehicle and its first "all-cryogenic" flight-tests with the Centaur.

• For the future, NASA has prepared a detailed "Ten-Year Plan." It predicts U.S. payload capabilities of 10,000 lb by mid-1963, 30,000 lb by mid-1964, 40,000 lb by mid-1966, and 55,000 lb by mid-1968. By the end of the 1960's according to Richard Horner, associate NASA administrator, U.S. astronauts will be on the threshold of circumlunar flight, with a manned lunar landing to come in the 1970's.

• By mid-1962, NASA's present pool of space booster vehicles—Redstone, Thor-Able, Atlas-Able, and Juno II—will drop out of the picture, to be replaced by Scout, the Agena-B with Thor and Atlas boosters, and Atlas-Centaur. Four Scouts are to be fired by July 1960, with six per year thereafter for the rest of the decade. The Thor-Agena-B will be launched first in the year beginning July 1961, with six per year for the rest of the decade. NASA will launch Atlas-Agena-B and Atlas-Centaur vehicles at a rate of eight a year from July 1961–63, with ten in fiscal 1964, followed by a dozen a year through 1969.

• The ten-year plan predicted two Saturn launchings in the year beginning July 1961, with two more in the following year and three in the year after that. Beginning July 1964, the Saturn firing rate will level off with four a year. Initial flight-testing of the 1.5-million-lb-thrust single-chamber Nova is expected in fiscal 1968, with two more shots in the succeeding fiscal year.

• Materially assisting the early flight schedule for the eight-engine Saturn cluster was the White House decision to give Saturn "top national priority" (along with Mercury). President Eisenhower okayed a 20 per cent boost in Saturn overtime and $113 million in additional funds to push Saturn and the F-1 superbooster which Rocketdyne is building. Dr. Glennan said the additional money would accelerate initial Saturn flight-tests one year and speed by 3 to 9 months the test-firings of the Saturn second and third stages. These will both employ lox and liquid hydrogen. A new Saturn second stage will be needed, with 200,000-lb-thrust lox-hydrogen motors in place of the elongated Titan booster originally planned.

• All told, NASA plans to get off 260 major satellites and space probes in the next 10 years. To forward this program, President Eisenhower asked Congress for $802 million in new obligational authority, a 53 per cent boost over fiscal 1960. Next to Saturn, NASA's biggest program will be Project Mercury, which will require $122,750,000 this fiscal year. Other important NASA programs: Scientific satellites, $41.7 million; lunar and planetary exploration, $45 million; liquid rocket technology, $40 million; Centaur, $47 million; and Thor-Delta, $12.5 million.

• Of lesser account in a month of budgets and plans: There is strong pressure within NASA to set up its own space-physiology group . . . The space agency is listening to industry proposals for solid motors with thrust-vector control, and may let contracts . . . Brookings Institution will study long-range social, technical, political, and economical aspects of the impact of space exploration for NASA under a $100,000 year-long contract.

MAN IN SPACE

• The sixth and last of the Little Joe shots, and first scheduled to pack a real Mercury capsule instead of a boilerplate model, has a good chance of taking place toward the end of this month. The January 21 shot marked the first completely successful test of the escape system under maximum loads, and bolstered expectations that the Mercury development will move promptly into long-range ballistic firings with the modified Redstone booster. Moreover, the long series of air-drop tests of the parachute-recovery and rescue systems, also blessed with success, have all but drawn to a close, and now point logically to an early ballistic flight.

• The 6-lb female rhesus monkey, Miss Sam, flown by the AF School of Aviation Medicine in the January 21 capsule, on a space-available basis, survived the flight in good spirits and with apparently no ill effects. Photographs and physiological measurements are expected to give a clear picture of the monkey's responses.

• The Mercury capsule itself now includes a glass picture window and a rubberized-Fiberglas cushion between heat shield and capsule face to buffer landing. Releasing the heat shield after re-entry will extend and inflate this cushion as a kind of skirt between capsule and shield which will vent air on impact to absorb shock.

• An informative and extensively illustrated summary of Project Mercury through 1959 has been issued by the House Committee on Science and Astronautics under the title, "Project Mercury, First Interim Report" (House Report No. 1228).

• The first test to simulate some of the effects of weightlessness for periods of longer than one-minute was successfully conducted by Capt. Duane E. Graveline, a 28-year-old flight surgeon at the USAF School of Aviation Medicine. After floating for a week in a tub of warm water, Capt. Graveline encountered marked physical and mental deterioration, including muscular atrophy and circulation difficulties. "We expect deterioration will be expressed as a marked inability to tolerate stress and g-loads," he commented. This means an astronaut in space for a week or more might be unable to cope with the re-entry problem, although little deterioration is expected during the 4.5-hr Mercury flight. This test will be followed by others of more complexity and control.

SPACE TECHNOLOGY

• The Titan ICBM can project a gross weight of 5000 lb into orbit, according to its engine developer, Aerojet-General, with most of this representing useful payload. If Titan's second stage were modified to use liquid hydrogen with liquid

oxygen, its gross orbiting capability, the company says, would climb to 9000 lb. In development work, Aerojet has already been able to boost the thrust of the first stage engine to 230,000 lb (nominal performance of 150,000 lb).

• Aerojet gives the following specifications for its "Senior," the first stage of NASA's Scout rocket system. Senior has a gross weight of 22,684 lb, an empty weight of 3584 lb, a burning-time of 33.5 sec, a thrust level of 111,800 lb, a total impulse of 4.1 million lb-sec and a specific impulse of 214 sec.

• The Air Force is sponsoring a design study of large solid-propellant rockets utilizing the "building block" concept. Such motors might have a gross weight of 500,000 lb, a total length of 60–70 ft and a diameter of 12–14 ft. Studies by Aerojet show that the U.S. highway system can accommodate rockets of about 12.5 ft in diam. Several companies have proposed segmented solid-propellant rockets with thrusts up to 3.5 million lb. Solid rockets in excess of 3.5-million-lb thrust probably will have to be built with special facilities on their own launching pads, according to Aerojet, while the segmented rockets can be assembled on the pads at much less cost.

• Nearly any company that can make solid propellant now has a scheme for a megaton-thrust solid-propellant space-vehicle booster. It would be interesting to see what transpires in the AF bidding. Advances in plastic motor cases make such powerful motors attractive in terms of mass ratio, but the physical properties of the huge grains that would be involved, and the prospects for combustion stability with them, leaves some room for second thoughts, especially with newer, high-energy propellants.

• Under NASA contract, Consolidated Systems Corp. has developed to the stage of prototype testing a small mass spectrometer, planned for a satellite in 1961.

• Aeronutronic Div. of Ford Motor Co. was selected as prime contractor in the ARDC study of the National Space Surveillance Control Center (Space Track) at AFCRC. The study covers cataloguing and computing satellite orbits, and design plans for expansion of the Center. Also involved in the study are Eastman Kodak, Page Communications, Dunlap and Associates, and Raytheon.

• Under a two-year contract from WADD's (previously WADC) Flight Controls Lab, Bendix Aviation's Eclipse-Pioneer Div. and Research Laboratories will develop and test hot-gas flight-stabilization and control systems for "semiorbital vehicles and missiles."

• The ninth Discoverer hit the deck without orbiting early in February.

• WADD's planned aerospace-dynamics simulator and analyzer—with capability for high vacuum, high and low temperatures, temperature gradients, three-direction vibration, roll, pitch, yaw, rotation, buffeting, etc.—will be built by the Ordnance Div. of Minneapolis-Honeywell Regulator under a two-year program involving several million dollars. Principal subcontractors involved are Cook Electric and Universal Match.

• People are talking plug nozzles for the 200,000-lb-thrust upper stage engine just bid on for Saturn.

• Electro-Optical Systems won the AF contract to develop a pilot-model ion engine.

• Payload for the first orbital test of NASA's Scout vehicle is slated to be a 100-lb micrometeorite package.

• Stanford Univ. scientists revealed that they succeeded in bouncing radar signals off the sun's corona in an experiment conducted last April. The experiment was similar to the one conducted in 1958 at Lincoln Laboratory, with Venus the target.

DEFENSE DEBATE

• The annual battle over the adequacy of the defense budget has broken out again between the Administration and congressional Democrats. Once again, a downward revision in the intelligence estimate of Soviet ballistic missile capability is the heart of the issue. Defense Secretary Gates says the Russians will not build a 3-to-1 margin over the U.S. in ICBM's as expected last year, but a smaller margin believed to be in the neighborhood of 2 to 1. He has admitted, however, that the revised estimate is based in part on an estimate of Russian intent—something usually frowned upon in intelligence circles.

• The period of the greatest Soviet missile lead will be mid-1962, Gates told Congress. At this time it is believed the U.S. will have about 180 operational Atlas and Titan ICBM's. The Russians accordingly are expected to have an ICBM force of 350 to 400 by this time. Gates argues that the Soviet lead in missiles does not mean a "deterrent gap" because of the great additional strategic deterrent power in the Polaris submarine, SAC bombers, the Navy's Sixth and Seventh Fleets and the overseas units of the Tactical Air Command.

• Soviet Premier Nikita Khrushchev livened this debate in a speech in which he hinted at a "fantastic weapon." This was followed-up shortly by start of the rocket test series over a 7700-mile range from Tyura Tam near the Aral Sea to a Pacific impact area southeast of the Marshall Islands. The Russians called their rocket a more powerful lower stage for a new interplanetary booster and claimed an accuracy of 2 km (1.24 miles) on their first shot. In Washington, observers were generally inclined to believe the Tass statements concerning the rocket shot, but there was no concensus as to K's "fantastic weapon." For what it's worth, several old Pentagon hands thought the Soviet leader was talking about a souped-up ballistic warhead—"something we've already given them credit for," commented one.

• As for the U.S. military budget itself, there were few surprises. The President sought $40,577 million in new funds for fiscal 1961, $70 million below the current fiscal year, and put defense spending at $40,995 million in fiscal 1961, up $50 million over this year. The trend from aircraft to missiles continues unabated; aircraft obligations will drop from $6,143 million this year to $4,753 million in fiscal 1961, while missiles will climb from $3,244 million this year to $3,825 million.

• Key items in the new budget include a 14th wing of B-52H long-range turbofan bombers for the Strategic Air Command, three new Polaris submarines and an oil-fired supercarrier for the Navy, and the Shillelagh antitank missile for the Army. Nike-Zeus will remain in development status.

• The President asked for a total of $3,951 million in research, development, test and evaluation funds in fiscal 1961, compared with $4,268 million this year. Major items (with current year in brackets) are: Aircraft, $446 million ($502 million); missiles, $1,481 million ($1,498 million); and military astronautics, $318 million ($408 million). The transfer of Saturn


Mc/S/A provides reliability with Gas Generators
in the successful accomplishment of all Project Mercury tests to date
Mc/S/A gas generators have proven their reliability in all tests of the Project Mercury landing system, developed by Radioplane, a division of the Northrop Corporation.
The gas generators provide the energy to eject the main and reserve Ringsail parachutes from their compartments in the test capsule. A folded nylon ejector bag, located beneath the parachute within the parachute compartment, is inflated at a controlled rate by low pressure (25-30 psia) solid propellant gases produced by the gas generator. The closed gas generator-ejector bag gas system eliminates gas losses and permits close control of ejection velocity at low ejection pressures. The gas generators are electrically initiated by a dual ignition system and the reserve unit incorporates a 1.25 second pyrotechnic time delay. Temperature of the gas introduced into the ejector bag is maintained below the burn-out temperature of the bag material.
Prototype test units were developed by Mc/S/A within 11 days from date of order. The gas generators have been operationally tested from − 60°F to +200°F and environmentally tested for humidity, shock, altitude, vibration, acceleration, radio noise, acoustic noise and salt spray.
EXPLOSIVE ORDNANCE
McCormick Selph Associates
HOLLISTER AIRPORT/HOLLISTER, CALIFORNIA

from the Army to NASA is responsible for the drop in the last account.

WEAPONS

• The Air Force selected four additional Atlas launching sites at Altus AFB, Okla., Dyess AFB, Tex., Walker AFB, N.M., and Plattsburgh AFB, N.Y., to bring to a total of 11 its Atlas bases and to 13 the number of its planned squadrons. Each base will have nine dispersed launching pads situated in underground silos hardened to 100-psi blast pressure; each will require $47 million and two years to complete.

• Present Atlas deployment plan provides for a soft Vandenberg AFB squadron of six pads using a single radio guidance net; the second squadron at Warren AFB, Wyo., will be the same, but the third squadron (also at Warren) will have some dispersal—three complexes of three pads each, each complex having its own aiming net. The fifth Atlas squadron at Fairchild AFB, Wash., will have the first all-inertial Atlas ICBM's completely dispersed and semihardened to 25 psi. The eighth Atlas squadron will introduce 100 psi hardening in underground silos.

• After a long dry spell (nine months without a flight-test success), Titan successfully demonstrated ignition of its second stage. The event was enormously heartening to the Air Force, which had supported Titan in the face of Congressional and other criticism. Before the Titan's flight-test success, Defense Secretary Thomas Gates had assured a House Appropriations Subcommittee that Titan had greater growth potential than Atlas, a better potential for storable fuel, and that it would "significantly increase the number of megatons you can deliver."

• In a more private vein, a high USAF official said Titan offered an earlier hardening capability than Atlas. It is planned that all Titan squadrons will be hardened to 100 psi in underground launchers, beginning with the first Titan squadron by mid-1961. The first six Titan squadrons will utilize radio guidance, however, and will be built in complexes of three each instead of having full dispersal. The seventh Titan squadron using all-inertial guidance and 100 per cent dispersal will be established about the spring of 1963. This squadron may also mark the introduction of storable propellants, higher-thrust engines and the ability to launch directly from the silo without raising the missile to the surface. A total of 14 Titan squadrons have been authorized.

• The Air Force and its contractors are working behind the scenes to reinstate the B-70 as a weapon system, and it is possible their efforts may produce an unexpected result: A decision in favor of Convair's latest proposal for a Super-Hustler powered by Pratt & Whitney's new J58 turbojet in place of GE's J79 in the present model. The J58 can deliver 23,000 lb of static-thrust without an afterburner, while the J79 can produce 16,500 lb with an afterburner. The improved specific fuel consumption of the J58 would make the Hustler all-supersonic for some missions, and give it a considerable range improvement for all missions, but would not increase its speed above the present Mach 2. It should be noted, however, that the prospect for a Super-Hustler is still tenuous; the Administration's present program provides for a "buy-out" of the B-58 in fiscal 1961, with a total of $3.1 billion obligated for 116 aircraft.

• Defense Secretary Thomas Gates plans a new appraisal of the nation's air defense requirements this year to determine whether the "mix" of missiles and manned interceptors decided upon in last year's "master" plan for air defense is still responsive to the Soviet threat. Gates said the plan provides for 16 Bomarc squadrons in the U.S. and 2 in Canada (with 8 of the total to be completed by mid-1961), but he said Bomarcs are vulnerable to really accurate ICBM attack because they require fixed sites while interceptors are more mobile. The Defense Dept. has earmarked $421.5 million for Bomarc-B and $111.4 million for Nike-Hercules in fiscal 1961; installations of the Hercules will be practically complete by the end of calendar 1960, while the Bomarc-B is scheduled into 1963.

• Pye Wacket is the name of an unique bomber air defense missile which Convair is developing with its own funds. Shaped like a saucer, it's designed to be fired from the tail of a bomber to destroy interceptors at greater ranges than conventional automatic weapons. One problem which has plagued previous tail-launched missiles has been a tendency for the missile to yaw 180 deg—i.e., turn in the direction of the launching aircraft.

• Solid-propellant missiles continue to extend their grasp on the military dollar. Latest big contract, in the amount of $82,599,690, went to Martin Co. for development of the two-stage Pershing, which will commence flight-testing at Cape Canaveral this year. The Air Force selected Aerojet to develop the second stage of Minuteman (Thiokol has the first stage). Boeing, which will assemble the missile in an $11 million facility at Hill AFB, Ogden, Utah, has awarded a subcontract to American Machine & Foundry Corp. and ACF Industries, Inc., to design and develop a railroad car launcher and control car for the mobile Minuteman. A total of 800 Minuteman ICBM's are planned, with 250 on railroad cars.

• Watch for the Air Force to order a design competition soon for its first "V/STOL"—a tactical fighter-bomber capable of verticle and/or short takeoff and landing. The airmen want the vehicle to be supersonic, have transocean ferry capability and be able to deliver large thermonuclear weapons. They believe the V/STOL capability is a must for a future generation of fighter-bombers in order to allow for dispersal and hardening.

• Initial flight-tests of the three-stage Minuteman solid-propellant ICBM will be conducted this year at Cape Canaveral. It is not known whether the firings will include live Aerojet second stages. The contract for the third stage has not yet been awarded, but Aerojet hopes to win it with a short, fat ($\cong$5 ft diam) rocket equipped with four moveable nozzles for control.

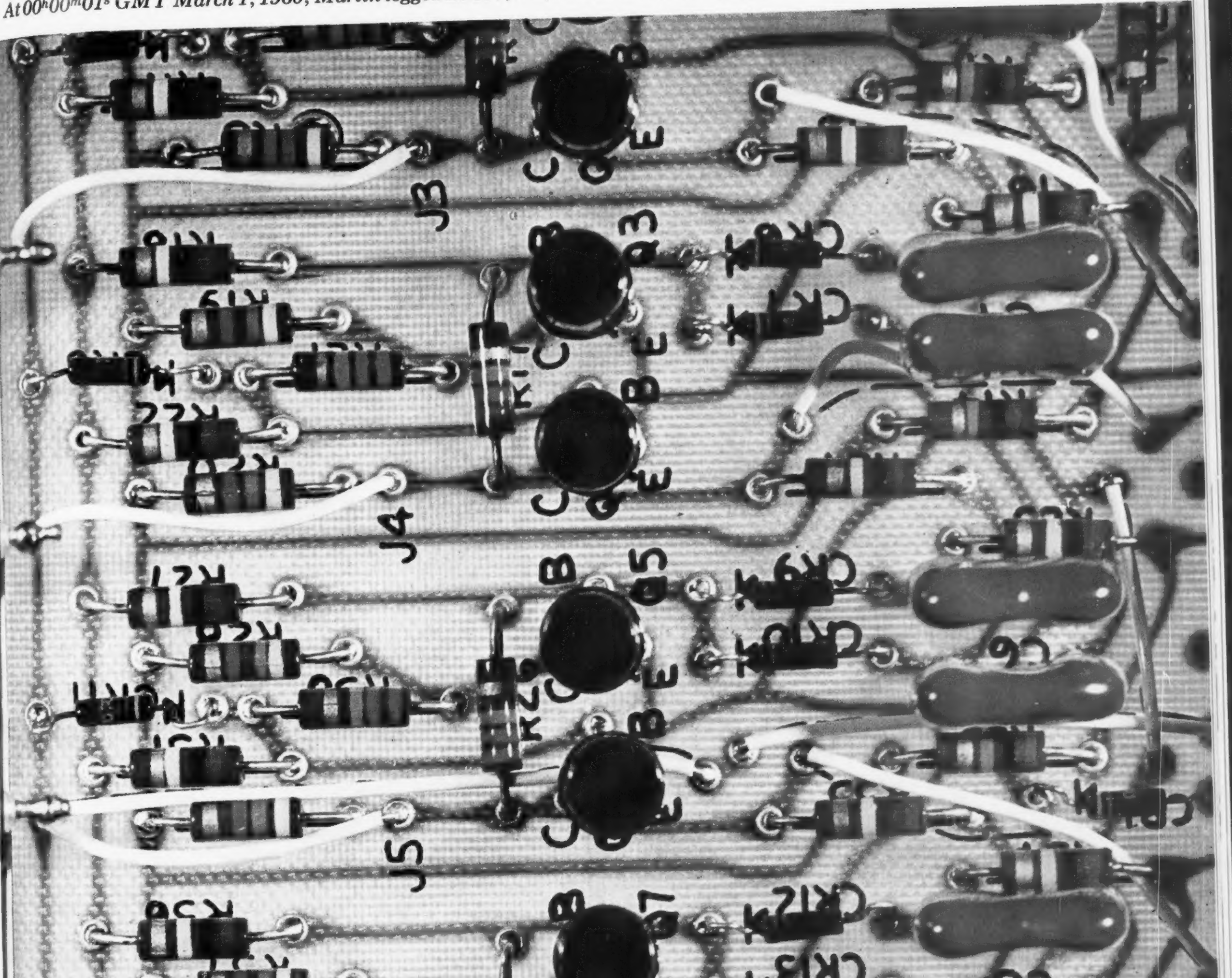
WIND-TUNNEL NEWS

• Arnold Engineering & Development Center is planning an indoor "space shooting gallery" capable of achieving velocities up to 5 mps and simulated altitudes of 60 miles. Using a supervelocity gas gun to accelerate a 2-lb model up to satellite speeds, the facility will measure 10 ft in diam and 1000 ft long. A unique feature of the $2 million "hypervelocity range" is the fact that the models will carry their own radio telemetry apparatus. AEDC has already developed transmitters and telemetry pickups capable of withstanding up to 200,000 g in two pilot facilities already in operation. A key assignment of the new range will be environmental studies of winged Dynasoar configurations which will operate in this speed-altitude regime.

• Originally designed to test

(CONTINUED ON PAGE 11)

At $00^{h}00^{m}01^{s}$ GMT March 1, 1960, Martin logged its 457,080,000th mile of space flight



Without electronics it is impossible to design, build, test, launch, guide, track or communicate with a missile. That is why **40% of Martin's 7,500 engineers are electronic/electrical engineers.**

MARTIN

GPL combined guidance

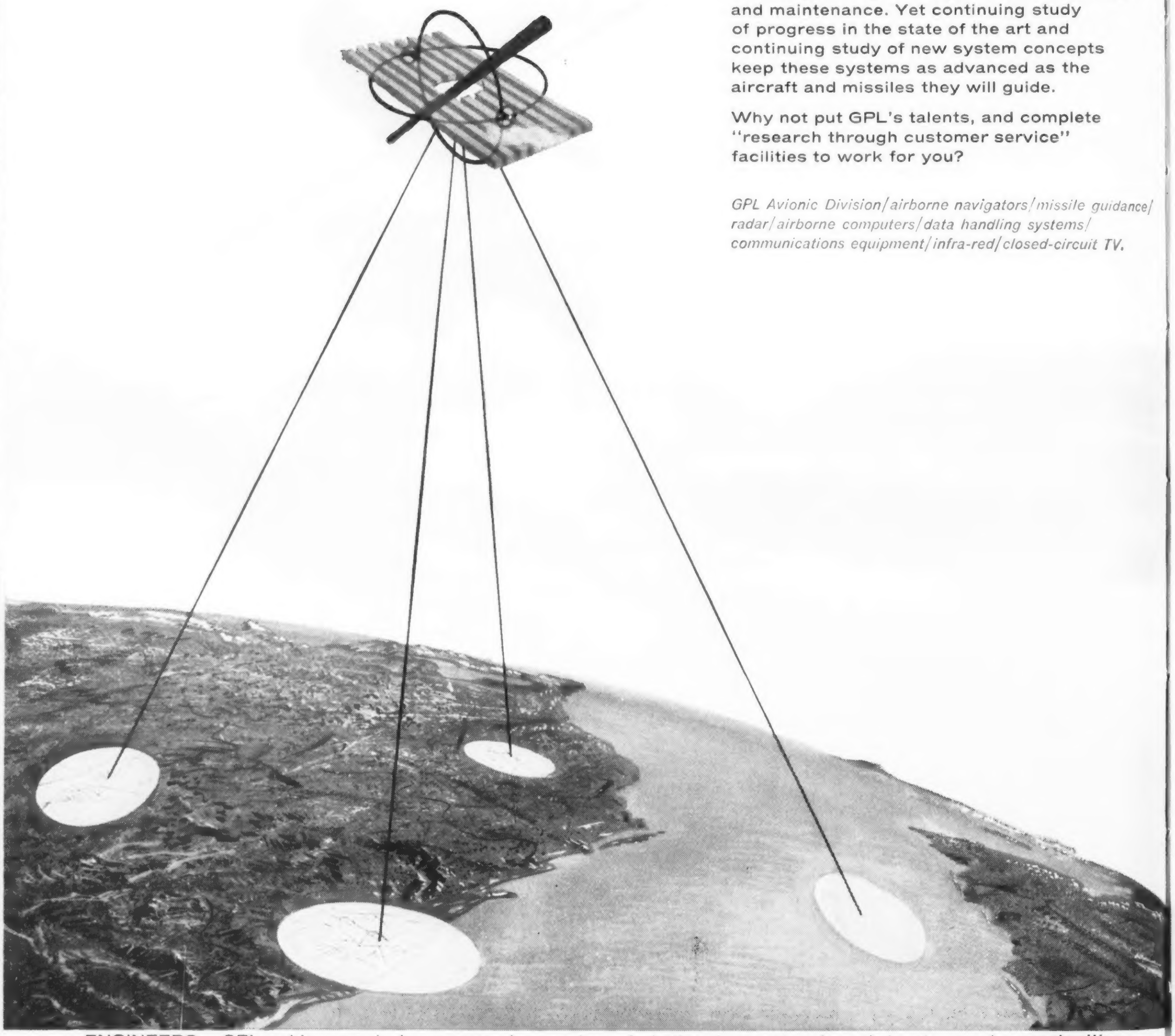
A.I.D. Navigation Systems

Combining state-of-the-art equipment in several fields to create new and superior systems for aircraft and missile guidance is still another GPL capability. One case in point is GPL's Astro-Inertial-Doppler A.I.D. navigation system—a stellar monitored, doppler tuned and damped inertial system—in which each element refines the others, and the system as a whole provides far greater inherent accuracies.

A.I.D. and other combined guidance and integrated systems now under development at GPL are particularly significant because they utilize *existing* systems and elements, *existing* components of proven reliability and accuracy, *existing* techniques for manufacture and maintenance. Yet continuing study of progress in the state of the art and continuing study of new system concepts keep these systems as advanced as the aircraft and missiles they will guide.

Why not put GPL's talents, and complete "research through customer service" facilities to work for you?

GPL Avionic Division/airborne navigators/missile guidance/ radar/airborne computers/data handling systems/ communications equipment/infra-red/closed-circuit TV.



ENGINEERS—GPL achievements have opened a number of challenging research and development opportunities. To be considered for these career positions, send resume of previous experience to Personnel Director.

GPL DIVISION

GENERAL PRECISION INC.

PLEASANTVILLE, NEW YORK

manned aircraft and atmospheric missiles, AEDC has been able to gear its $300 million physical plant to the requirements of rockets and ballistic missiles in time to provide data on many pressing development problems. To further expand its ability to test rocket engines under simulated high-altitude conditions, AEDC will build a vertical rocket-engine test cell this year capable of handling a 200,000-lb-thrust engine at a simulated altitude of 140,000 ft. It is also seeking $9 million for a new vertical cell capable of testing rocket engines up to 1.5-million-lb thrust.

ELECTRONICS

• Molecular electronics, promising more wonders than Aladdin's rustic lamp, took the public stage with authority last month." This is the way to go for payoff in space activities," said Col. W. S. Heavner, AF program chief of WADC's Electronics Technology Laboratory, at a recent Westinghouse showing of some 20 molectronic devices, certain of which were formed during the process of drawing the base semiconductor.

• Molecular electronics involves synthesizing solid-state effects, such as Seebeck generation and Peltier cooling, with p-n junctions in a single piece of semiconductor, such as a strip of germanium crystal. The domains and boundaries of these effects are produced in the semiconductor by doping, etching, plating, cutting, and other easily automated processes already common to solid-state technology.

• The sum of these effects is a desired function—amplification, filtering, switching, what have you—from the single piece of material with one set of leads. The internal functioning of the functional unit does not have a strict analog in circuit design with components. It is hardly necessary to comment on the lowering of size and weight of devices and the improvement in their reliability by this technique.

• This method of electronic design and the automatic drawing and processing of thin uniform strips of semiconductor material has been solved in fundamentals at least by the Westinghouse research group, headed by S. W. Herwald. Other companies, such as Texas Instruments and RCA, appear not far behind.

• The Air Force, which expects the major impact of molecular electronics to hit industry in about three years, and to enter experimental space work long before that, predicts that the new technology will drastically change the current picture of electronic component and equipment design and manufacture. The Air Force will continue and expand Westinghouse's pioneering program, back programs in other major companies—such as Texas Instruments, which will design and build an entire molelectronic digital computer for the AF this year under a $1 million contract—and will spur industry-wide participation in molecular electronic advances through its operational requirements.

• Harry Kihn of RCA Laboratories previewed this rapidly evolving technology in the May 1959 *Astronautics*, page 44. Missile Market (see page 88) comments further on recent developments.

• Hughes Aircraft's research laboratories turned a neat trick by devising a doped-silicon "solid-state ionization chamber" (p-n junction) the size of a pinhead that when struck by a nuclear particle emits a pulse which can be counted, measured, and analyzed as to species. The device, which should immediately improve on the performance, size, ruggedness, and cost of present radiation detectors, will have wide application in nuclear power controls, cancer treatment, basic nuclear research, and space science. In particular, according to S. S. Friedland of Hughes, NASA officials are interested in a three-dimensional array of the devices for radiation-study satellites and probes to supplement or replace the planned ones with photographic plates, which require recovery. Properly instrumented, such an array would, by means of a telemetry system, give a continuous and immediately deciphered record of the radiation tracks through it.

• Western Electric and Bell Labs announced that they are producing computer memory units based on the Twistor development.

MATERIALS

• A group of researchers under Herbert A. Pohl at Princeton Univ. has produced three different groups of thermoplastic semiconductors, including ones based on polyacrylonitrile as early as last October. This is one material reportedly used in Russian experiments with plastic semiconductors.

• NBS scientists W. E. Reid and A. Brenner have developed a method of vapor-depositing high-purity tungsten on both simple and complex metal surfaces. The process involves reducing gaseous tungsten hexafluoride with hydrogen by passing it over the heated object to be plated.

INTERNATIONAL

• Russian experimenters picked up their marbles and retired for rumination after announcing that their second long-range shot into the Pacific, on January 20, was a success, having traveled 7762 miles to a point 1.24 miles from the calculated target. Russian commentators did not spare the horses in predicting space feats in terms of this performance. Among them, A. A. Blagonravov at the COSPAR meeting (see page 25) said, "It is obvious everything is being done so such a ballistic flight (to Mars) will be possible at the end of 1960, at a time when Mars will be relatively close to earth."

• The first rocket designed and made in Israel will be fired there some time this year for meteorological and cosmic-ray studies, according to Moshe Arens, president of the Israel Astronautical Society. He also announced that the Society will soon start operating a satellite-tracking station located on the campus of the Technion, on Mount Carmel. The station will use five powerful telescopes on loan from the Smithsonian Institute of Washington, D.C., and will be manned by members of the Israel Civil Aviation Corps.

• A 14-man Japanese mission team, headed by Yoshinaga Seki, president of Mitsubishi Electric, will visit the U.S. and Europe toward the end of March to survey rocket research, manufacturing, and operational developments. The U.S. Government recently announced that it would assist Japan in rocket development.

• The U.S. has "informally agreed" to supply rocket vehicles for six British satellite payloads, the first of which will be attempted late in 1961. Most of the rockets will probably be four-stage Scouts, with a payload capability of 200 lb. British satellite payloads will include ion and electron studies to measure temperature and concentrations of these particles in space, solar radiation studies and measurements of primary cosmic rays. The U.S. is also negotiating with several other countries on cooperative space ventures.

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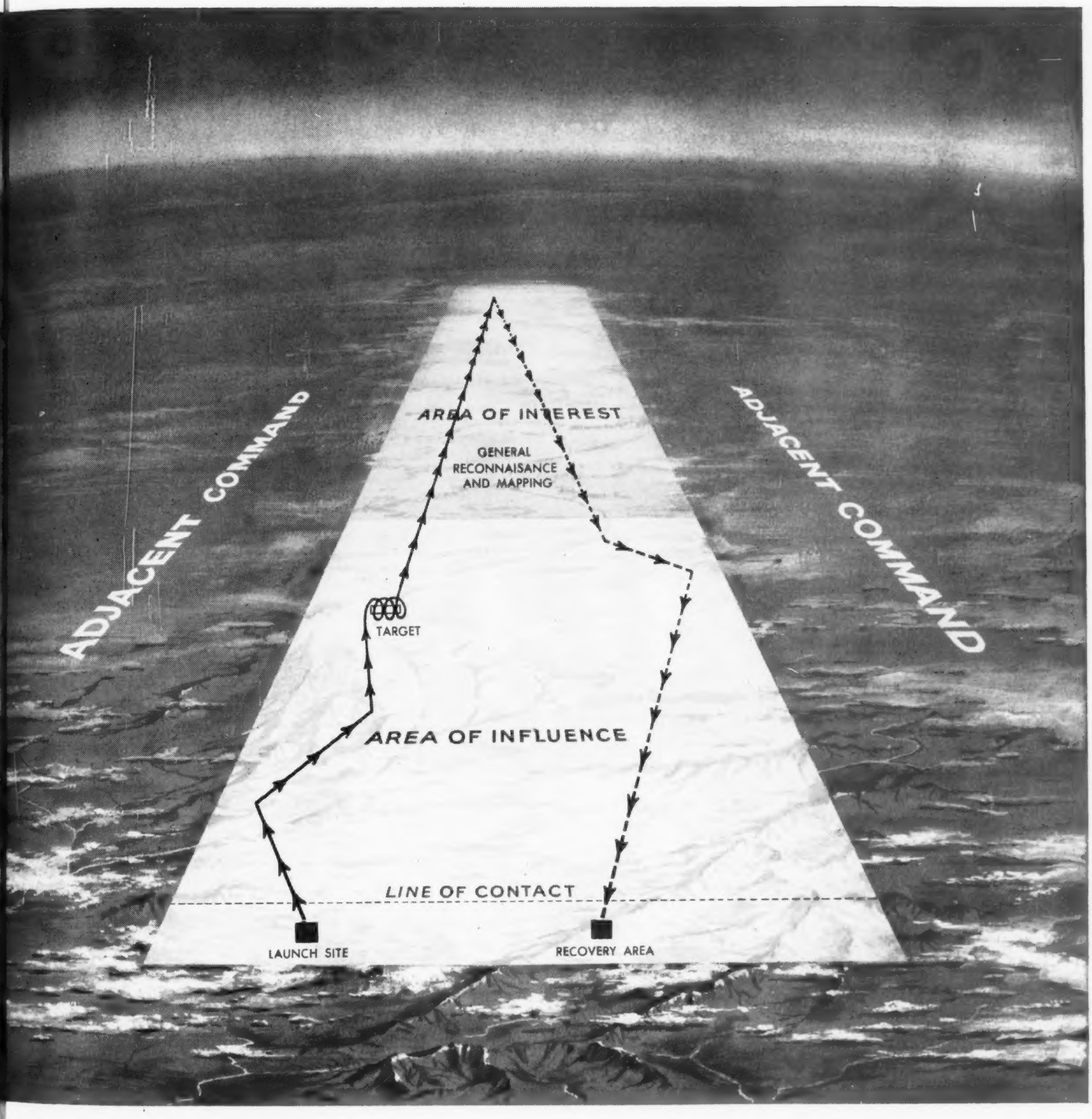
Miniature Inertial System surveillance drones



Flight path programmed for a typical advanced-drone mission is shown in this diagram. The Honeywell miniature inertial guidance system will direct the aircraft from launch to target and beyond, and back to recovery area without ground commands.

From the patent office

By George F. McLaughlin

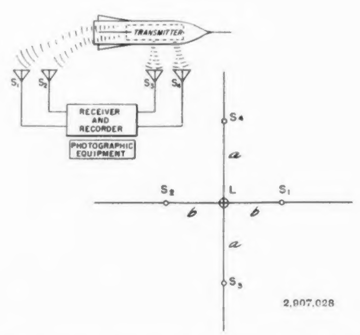
Method of Determining Trajectories

In testing and developing missiles, it is necessary to determine how trajectories vary with changes in parameters, such as missile shape, arrangement of control surfaces, and guidance means. Optical or radar techniques for trajectory determination are limited in scope. The former are handicapped by adverse weather, and radar installations usually require that the missile under test carry bulky and expensive transponder equipment.

The patented method makes use of the interference phenomena between electromagnetic radiation which travels from the missile to receivers and radiation which is reflected to the receivers.

Signals of constant frequency and amplitude are sent from a radio transmitter on the missile. Located at a fixed point in space is the antenna of a conventional receiver. The antenna is located at a fixed distance above a flat reflecting surface on the ground or a body of water. The strength of the electromagnetic signal in relation to time is continuously recorded at three or more fixed stations.

Shown in the accompanying diagram is a preferred arrangement if four antennas (S_1, S_2, S_3, and S_4) are used; "L" is the location from which the missile is launched in a direction toward S_4.



Plan view showing arrangement and location of receivers, and a block diagram of the system.

Apparatus for recording includes photographic means responsive to signals for determining at least one reference point of the trajectory at a known time during the initial period of missile flight. At that period, a first interference signal is recorded. Records of the early stages of the flight are made with fixed cameras or tracking cameras.

Standard photogrammetric reduction procedures are then used to show the position of the missile in space as a function of time. Recordings of interference are made with a time base common to both interference and metric photographic recordings. This provides position in space and the interference record as a function of common time. Correlation is made through this common time base.

Patent No. 2,907,028. Apparatus for Trajectory Determination. Robert J. Stirton and George Leitmann, China Lake, Calif., assignors to the U.S. Navy.

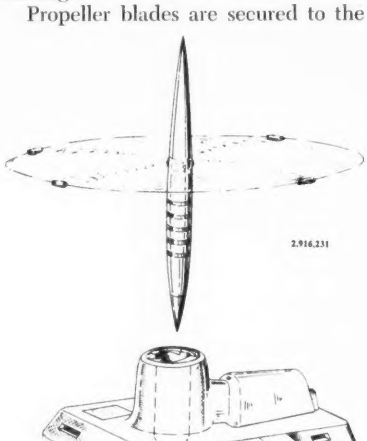
Jet-Powered Launcher for Missiles

Applied for less than two years ago, this patent covers a novel method of launching missiles in order to reduce their size and cost. Involving jet-powered rotors, the system raises a missile and launches it with spinning motion without flash and noise on the ground. Missiles may be kept hovering to facilitate aiming or other control operations impractical at high velocities.

The missile comprises the usual conical nose, cylindrical body, and thrust nozzle. The rotary launching craft has a tubular fuselage, its upper end open to receive the missile, and a tail cone at the lower end. Radially mounted at the top of the fuselage are propeller-supporting studs housing the electronic equipment of the launching vehicle.

Rotatably mounted on the studs is a propeller head with a cam follower. When the follower is moved outward, it engages a cam securing the head to the stud and fuselage. When the head is moved, the cam and follower disengage, permitting angular movement of the head with respect to the fuselage.

Propeller blades are secured to the outer end of the head. Blades are hollow, and store fuel for the jet engines installed at blade tips. Centrifugal force feeds fuel to the engines.



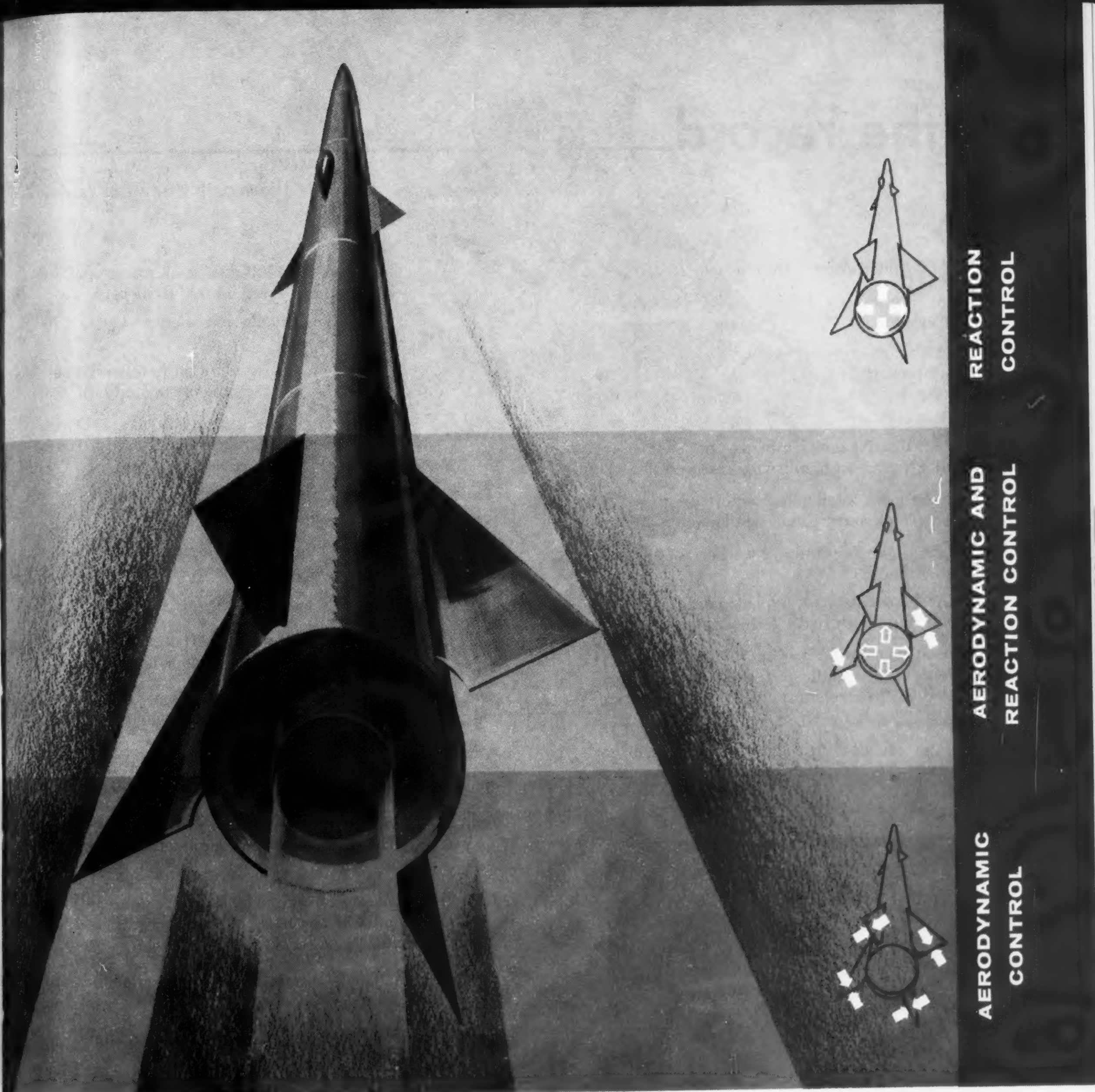
Jet-driven propeller-bladed launching vehicle and missile as launched from the motor-driven clutch of the catapult.

Another basic part of the invention is the catapult. It has a rotatable chuck with a throat for receiving the fuselage of the launching craft. Cam lobes on the upper surface of the chuck are used for the engagement and easy discharge of the craft. The chuck is driven by a motor within a housing.

In operation, the missile is inserted into the launching-craft fuselage. This assembly is placed in the catapult with the propeller lugs resting in the chuck lobes and the blades flat. When the motor is speeded up, the chuck and launcher are rotated at high speed. Centrifugal force moves the head outward, turning the blades to a lifting pitch. The launching craft and missile rise, leaving the catapult.

Following these procedures, the missile leaves the launching craft by rocket power. The craft returns to earth under control for reuse.

Patent No. 2,916,231. Missile Launching Device. Paul R. Gley, Saddle Brook, N.J.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For the record

The month's news in review

Jan. 6—AF test-fires Atlas 5000 miles.

Jan. 7—Navy tests new Polaris self-contained guidance system.

Jan. 8—Soviet Union announces it will fire a series of "more powerful rockets" into the Central Pacific starting Jan. 15, as part of its spaceflight program.

Jan. 9—U.S.S.R., Poland, and Czechoslovakia join COSPAR plan on basic space research.

Jan. 10—Government intelligence report predicts 1962 as year Communist China will launch a satellite.

Jan. 13—Polaris carries dummy warhead 900 miles down Atlantic.

—NASA decides to replace Saturn's Titan second-stage with hydrogen rockets.

Jan. 14—President asks NASA Chief T. Keith Glennan to report on additional funds needed during fiscal 1961 "to accelerate superbooster program."

—Thor achieves 1700-mile goal, using modified Thor motor with about 15,000 lb more thrust.

—AF launches Javelin sounding rocket to 670-mile altitude.

—AF reports recent firing of an Aerobee-Hi nose cone that points its instruments to study the sun.

Jan. 15—Soviet Union agrees in principle to join Operation Space Warn, international system for tracking man-made space vehicles.

Jan. 16—NASA 100-ft-diam plastic balloon inflates at 250-mile altitude.

Jan. 17—NRL announces development of Project Madre, a radar that bends over the horizon and provides extremely long ranges with relatively low power.

—AEC discloses that Snap-III is still producing power after a year of continuous operation.

Jan. 18—NASA's R&D budget for fiscal 1961 is increased to $600 million from previous $325 million.

—President nominates AF Assistant Secretary Joseph V. Charyk to be undersecretary.

Jan. 20—Soviet Union fires multistage rocket 7762 miles and drops nose cone within one mile of its target in the Pacific.

Jan. 21—Monkey Sam rides Mercury capsule to altitude of 9 miles in successful test of emergency-escape system.

Jan. 22—ARDC and Westingtouse Electric demonstrate line of molecular electronics systems.

Jan. 23—AF X-15 completes fourth powered flight.

Jan. 26—Two Atlas' fired from Vandenberg AFB and Cape Canaveral hit targets.

Jan. 27—Lockheed unveils Agena engine that can be restarted in space to change the orbit of a satellite.

—Polaris achieves its goal; Titan dies on pad; and Minuteman equipped with prototype control and automatic pilot guidance system meets its test objectives.

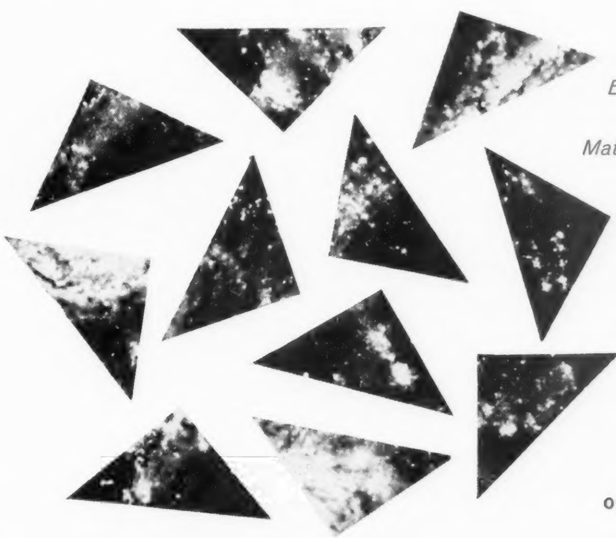
—NASA chief discloses plan to orbit 375-lb payload around moon this spring.

Jan. 28—NASA submits its 10-year space program to Congress, calling for manned flight to the moon in the 1970's, 260 satellite launchings, and deep-space probes.

—AF dedicates its Satellite Test Center at Sunnyvale, Calif.

Jan. 30—Maj. Gen. John B. Medaris, AOMC commander, retires.

Jan. 31—Soviet Union fires second missile into Pacific.



International scene

By Andrew G. Haley

THE BEST laid schemes o'mice and men . . ." In the last issue, a complete factual account of astronautics in the People's Republic of China (Peking) and in the Republic of China (Taipei) was promised for this issue and succeeding issues. The "gang agley" in this case is not lack of factual material, but delay in obtaining accurate translations of material. For example, résumés of five excellent articles from Taipei were rejected by the Air Attaché of the Republic of China Embassy in Washington, and the authors directed to supply complete translations, fully authenticated and approved by the appropriate experts in the Academy of Sciences. Similar difficulty has been experienced in obtaining translations of material from the People's Republic of China. English abstracts of the articles have therefore been abandoned in favor of obtaining translations of the complete articles.

° ° °

A high degree of cooperation has been achieved between the UN's 24-government Committee on the Peaceful Uses of Outer Space and the IAF. In the field of the natural sciences, the IAF representatives to the Committee are Franco Fiorio, the Italian member of the committee, and T. M. Tabanera, the Argentinian member, while in the field of social sciences the IAF is represented by Jacek Machowski (Counsellor, Permanent Mission of the Polish People's Republic to the UN) and the writer. The 24 nations participating have been advised of the desire of the IAF to furnish advisory Working Groups on all aspects of astronautics.

The cooperation offered by the IAF is of a most distinguished order, as the work of organizing the IAF International Academy of Astronautics has been completed by Theodore von Kármán, and an organizing committee setup consisting of many of the greatest scientists from all parts of the world.

In the field of the social sciences, work on the organization of the Institute of Space Law of the IAF is largely completed by the circulation among committee members of the proposed statutes of the Institute, and the decision to include in the membership initially the more than 250 world-renowned lawyers who presently constitute the IAF Permanent Legal Committee. This work has been done under the leadership of Christopher Shawcross, Q. C. (UK), John Cobb Cooper (U.S.A.), Michel Smirnoff (Yugoslavia), Robert Homburg (France), Fritz Gerlach (German Federal Republic), and the writer.

The IAF is particularly fortunate in that, as a nongovernmental international organization, it has already achieved recognition by and affiliation with UNESCO, the International Telecommunication Union (ITU), and the UN Economic and Social Council (ECOSOC).

° ° °

On the other side of the world, Olgierd Wolczek of the Institute for Nuclear Research in Warsaw reports that the Polish Astronautical Society now has seven branches—in Warsaw, Cracow, Katowice, Wrockaw, Lublin, Mielec, and Gdansk. Prof. Wolczek attributes this remarkable growth to the impetus given the cause of astronautics by the late vice-president of the IAF, K. Zarankiewicz.

° ° °

Eugen Sänger, with his usual patience and scientific excellence, has answered a document submitted to him by Vernon G. Leopold and A. L. Scafuri of the Special Committee on Space Law of the State Bar of Michigan, concerning their theory that the jurisdiction "touchstones" for UN space authority should be based upon "orbital and superorbital spaceflight trajectories." Dr. Sänger points out that he is "a thorough layman in the field of jurisdiction" but that he is becoming steadily convinced that it is necessary to delegate "some of the functions of national sovereignty to international bodies." Dr. Sänger reviews the history of jurisdiction relating to "airspace," and states that nothing has caused him to change his opinion that the flying altitudes of aerodynamic and aerostatic vehicles cannot exceed roughly 35–50 miles, for physical reasons—hence "my opinion rendered in Hearing Report 1433 of the U.S. House Committee on Science and Astronautics to the effect that national air space should be limited to that altitude."

Messrs. Leopold and Scafuri asked Dr. Sänger the concrete question, "Does the proposed dichotomization of spaceflight into two broad categories,

(CONTINUED ON PAGE 93)

Titan Takes a Step

Last month was a landmark in the Titan development, seeing the first firing of the 41-ft, 24-ton second-stage engine in the fifth successful launch of the flight-testing program. Above, the second stage.

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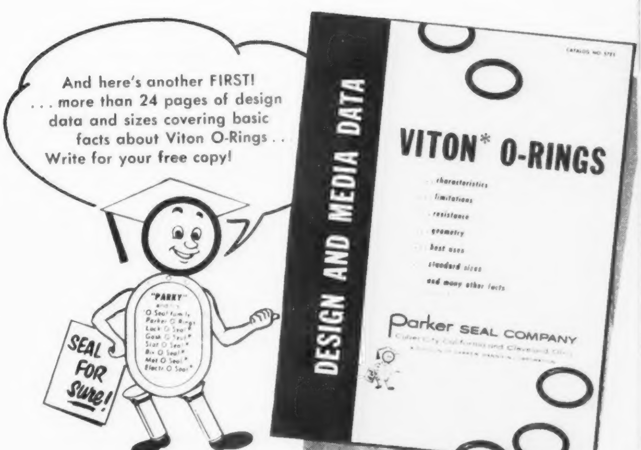

One of the first to embark upon a research and development program for Viton O-rings, Parker Seal Company now makes another significant advance in this versatile high temperature material by offering Viton O-rings in all A.N. or A.R.P. standard sizes. This means faster delivery and greater economy for all these popular O-ring sizes. It's another plus result of ***responsible leadership*** *in O-ring engineering by Parker.*

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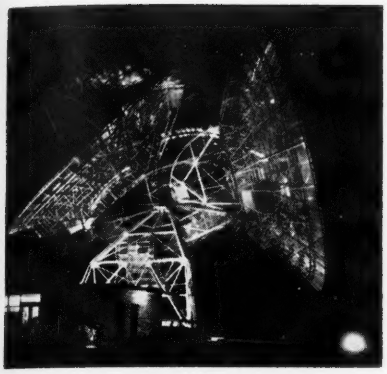


COVER: *The National Radio Astronomy Observatory's 85-ft-dish radio telescope, built by Blaw-Knox, reflects the new romance of radio astronomy in this multiple exposure catching its rotation through a heavens-scanning arc (see page 33). (Full-color ASTRO cover plaques, 11 x 12 in., are available from ARS Headquarters for $2.00 each.)*

Astronautics

MARCH 1960

Documents of Distinction

Like the sorcerer's apprentice popularized by Disney, the modern space technologist finds himself all but submerged in a flood of printed matter ranging from space cadet manuals to unadorned differential equations. Spoken words on space pour over him from many sources. Every day at several places in the nation professional societies hold meetings, often with parallel sessions, vying with each other to embrace the omnifarious subjects of space technology.

In these noisy circumstances, it behooves the members of the American Rocket Society to speak only when they have something to say. The chairmen and members of our numerous technical committees bear the responsibility for creating meetings only in response to a genuine need. After initiating a meeting they should insist on thorough (and prompt!) review of the submitted documents and accept only those judged sufficiently significant, sound, clear, and brief. This process will of course disappoint certain prospective authors, but it will earn the appreciation of many busy professionals who do not have time to refine the gold from the dross, and more importantly, it will earn for the ARS a deserved reputation for technical excellence.

We realize that execution of a policy of careful discrimination among scientific papers is difficult. Our less technical communications with laymen, youths, and ARS luncheon guests must also be monitored to the credit of the Society. As Gilbert and Sullivan put it, "A policeman's lot is not a happy one!" I am persuaded, however, that discipline exercised by the technical committees and program chairmen will in the long run pay valuable dividends for the ARS.

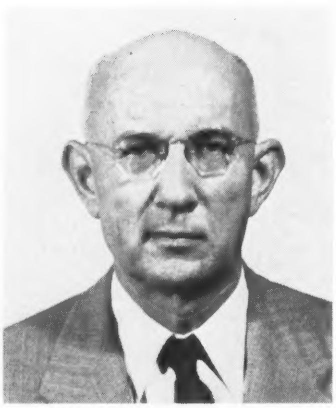
Howard S. Seifert
President, American Rocket Society

Radio interferometry

This communication technique promises to meet one major challenge of space exploration—measuring distances with a precision of a fraction of a wavelength at stellar ranges

By Marcel J. E. Golay

PHILCO RESEARCH DIV., PHILADELPHIA, PA.



Marcel J. E. Golay, born in Neuchatel, Switzerland, received an electrical engineer's licentiate from the Federal Institute of Technology of Zurich in 1924. After working for the Cable Dept. of Bell Telephone Laboratories from 1924 till 1928, he attended the Univ. of Chicago, where he received a Ph.D. in physics in 1931. Dr. Golay joined the U.S. Army Signal Corps Engineering Laboratories in 1931, and there did research in underwater sound detection and IR, developing the sound-ranging equipment used during WW II to locate large enemy guns; the Golay Pneumatic Radiation Detector; and radio relay equipment utilizing the Golay Delay Line. He also did research on information and coding theory, and published some of the earliest work in this field.

Dr. Golay left SCEL as chief scientist of the Materials and Components Dept. in 1955, and has since been a consultant to Philco and Perkin-Elmer. In recent years, he has invented the Golay Coils used in nuclear magnetic resonance work and the Golay Columns used in gas-liquid partition chromatography.

The author of some 40 technical papers and holder of 15 patents, Dr. Golay is a member of many societies, including ARS. He was recipient of the Harry Diamond Memorial Award from IRE in 1951.

If we sought the words which most closely characterized, or rather symptomized, the decades of the first half of this century, we could perhaps, and not without much controversy, establish some such list as: 1st decade . . . PROGRESS; 2nd decade . . . DEMOCRACY; 3rd decade . . . MONEY; 4th decade . . . AGGRESSION; 5th decade . . . ATOM. Less controversy would be encountered if we chose SPACE as the watchword of this century's sixth decade. This word epitomizes the physical accomplishment of escape from the gravitational attraction of the earth. But more than that the word, "Space," evokes man's eternal hope of reaching beyond—beyond the physical bonds of his immediate surroundings, and beyond the limits of his present knowledge. And, as do all rallying cries, this word connotes several concepts.

To Euclid, space was that without which geometry could not be. To yesterday's man in the street it meant just "room." And today it means all outdoors beyond the stratosphere, be it the locale of an artificial satellite's orbit, or interplanetary space, or interstellar space, or the intergalactic space which extends to the confines of our universe.

The New Space

To be sure, speculation about space accessible to man's sight is as old as civilization. Now something has been added to our speculation, for rocket technology of the past decade has opened the thrilling possibility of sending exploring devices into this new-found space. Thus, to the man of today, space means *physically accessible space* in which we shall at first place devices which emit visible or radio signals, and eventually devices with which we shall have two-way communication. The first may be simple reflectors of the sun's rays or emitters of continuous wave signals, such as the first Sputnik. The latter may be observing devices transmitting to ground stations astronomical or geographic observations, or they may be active or passive radio relay stations.

It is about active radio relay stations that this article is concerned. Before examining the specific communication problems to be solved, certain aspects of the magnitudes involved should be considered, for these aspects reveal the curious side of the general problem dealt with here.

We know that escape from the earth's gravitational field—whether it be partial escape for a satellite or total escape for an instrumented planetoid having its own solar orbit—is very expensive in terms of rocket thrust. What is not widely realized is the enormous increase in range which a little more thrust will permit us to achieve and, by the same token, the enormous increase in electronic sophistication which must also be achieved, if we wish to maintain radio contact with the vehicles we launch.

Consider, for instance, the thrust requirements for a satellite on a circular orbit 700 km above the earth. Assuming a nonrotating earth without an atmosphere—assumptions which introduce slight errors partially canceling each other—we calculate that we need an initial thrust of 8.1 km/sec, which will launch our satellite on an elliptical orbit with its apogee 700 km above the earth. A terminal impulse of only 0.2 km/sec given at the apogee will serve to prevent the satellite from falling back toward the earth. This small additional thrust will place the satellite in a new orbit, this time circular, 700 km above the earth.

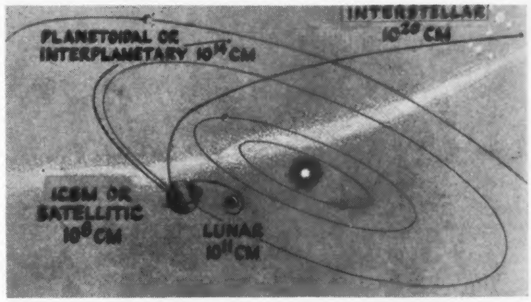
At Escape Velocity

Now, at the other extreme, look at a vehicle launched with a velocity of 16.7 km/sec into a hyperbolical orbit of escape with respect to earth. This vehicle will have a residual velocity of 12.4 km/sec with respect to the earth after it has substantially escaped our planet's gravitational pull. And if this residual velocity is in the direction of the earth's own velocity (30 km/sec) around the sun it can be added to that velocity for a total of 42.4 km/sec. This is just the impulse required to escape from the sun's own gravitational field, when starting near the earth's orbit. Thus, the 16.7 km/sec initial impulse at the earth's surface is just that required for launching our vehicle on interstellar travel within the Milky Way.

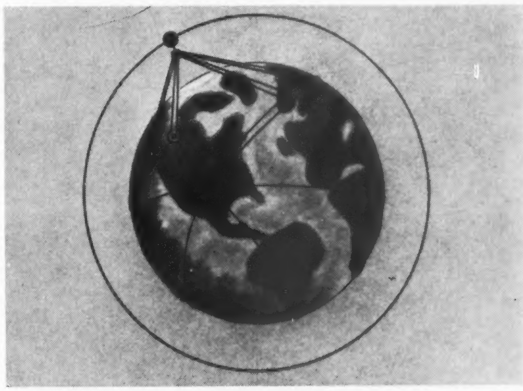
There are several other interesting possibilities which are intermediate within these two extremes. A few of them have been listed in the table on page 24. The first column of this table describes the orbit into which the vehicle is launched—satellitic, planetoidal, or interstellar. The second column gives the total specific impulse required in kilometers per second, and the third gives the approximate ranges involved.

The curious side of the problem dealt with here is revealed by that third column, for while the impulse data given in the second column represents a succession of moderate increments, the range increments which can be noted in the third column are extraordinary. These figures serve us notice that the urgency of today's propulsion problem may be re-

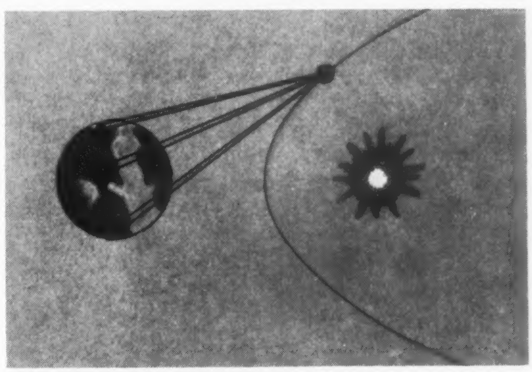
Interferometric Ranges



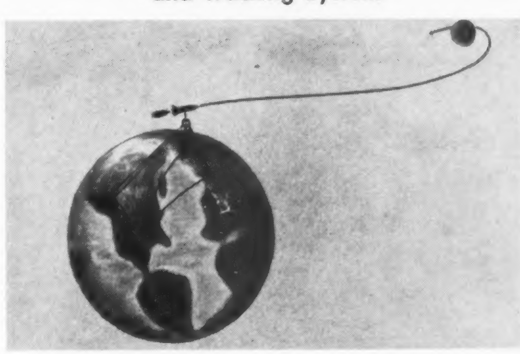
Satellitic Interferometric Tracking System



Planetoidal Interferometric Guidance and Tracking System



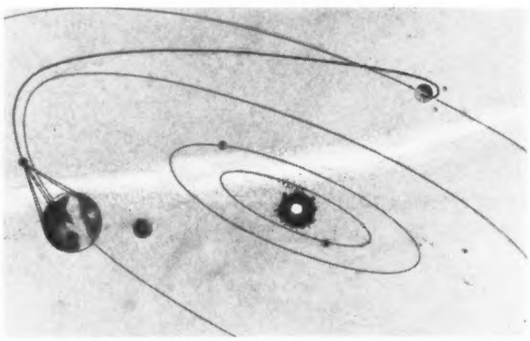
Lunar Interferometric Guidance and Tracking System



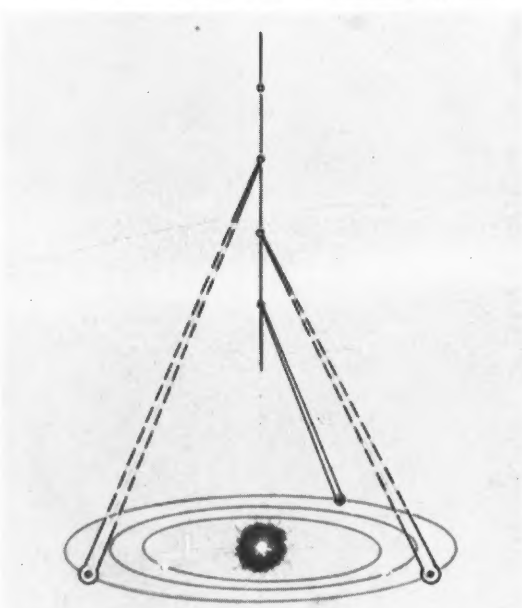
placed with dramatic suddenness by the urgency of tomorrow's communication problem.

It is also apparent from the third column of our table that three orders of range magnitude are under consideration: Satellitic, planetoidal, and interstellar. The first is handled with comparative ease with modern communication techniques while the rewards offered at this time by the third appears hardly commensurate with the technical and human difficulties, especially when an experiment may extend over several thousand generations. But a real challenge, with rewards commensurate with the difficulties, is presented by the general problem of establishing communication with interplanetary vehicles. Within this general problem there are two generic tasks to be considered.

Interplanetary Interferometric Guidance and Tracking System



Interstellar Interferometric Tracking System



The first task is the establishment of message transmission to, or from, a manned interplanetary spaceship making a journey to Venus or Mars. The second task is the establishment of communication with such a vehicle, or with an unmanned vehicle, to keep track of its range, and incidentally to obtain valuable quantitative data on our solar system. We shall now examine these two apparently different tasks and discover an interesting relationship between them.

One-Way Communication

Consider first the establishment of message transmission to a spaceship. This one-way communication will have to take place in a certain portion of the radio spectrum. S-band (10-cm wavelength) appears to be the best choice because it is a compromise between the lower frequency radio waves, which propagate anomalously in the ionosphere, and the higher frequency waves, which are not amplified as efficiently as the lower frequencies in even the best radio receivers.

Now, we note that the relative velocity of the vehicle and earth stations may be as high as 10 km/sec. The Doppler effect caused by this relative velocity will be rather large; for, if we divide this relative velocity by the wavelength of the signal radiation utilized (10 cm for S-band), we reach the conclusion that, when the vehicle recedes from the earth, the frequency of the earth-emitted signal will arrive at the vehicle with a frequency *100 kc lower* than when emitted.

We note secondly that the signals received by a planetoid nearly in opposition with respect to the sun have been enormously weakened by a travel of some 300,000,000 km. The communications engineer knows how to receive such weak signals when he knows also their exact frequency. He "narrowbands" his receiver; that is, he makes his receiver sensitive to changes in the strength of the "carrier" signals which are very slow—of the order of a fraction of 1 cps. This is (CONTINUED ON PAGE 48)

Line-of-Sight Range Jumps

Orbit	Total Impulse, km/sec	Max. Line-of-Sight Range, km
Circular		
700 km above earth	8.3	3000
5000 km above earth	9.9	10,000
Circular around sun	11.2	300,000,000
Elliptical around sun	14.4	1,000,000,000
Interstellar within our galaxy	16.7	100,000,000,000,000,000

Delegates at COSPAR's opening session at Centre Universitaire Méditerranéen lend an attentive ear to the speakers.

Report on COSPAR

Dream of international cooperation in space research moves closer to reality at Nice meeting. . .250 delegates from twenty countries attend COSPAR-organized First International Space Science Symposium

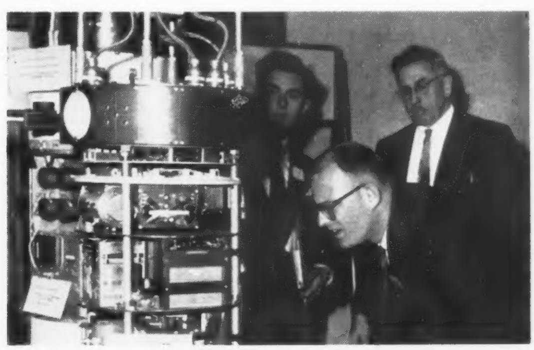
By Irwin Hersey

NICE, FRANCE—The dream of international cooperation in space research moved a step closer to reality at the meeting of the Committee on Space Research (COSPAR) of the International Council of Scientific Unions and the First International Space Science Symposium, organized by COSPAR, held here in January.

The Symposium drew an attendance of 250 delegates from 20 different countries, including the U.S.S.R. and Poland, who listened closely to almost 100 papers in the course of the five-day meeting. Meanwhile, at COSPAR sessions, delegates hacked out agreements on international cooperation in many different areas, while informal conversations held in the chilly corridors of the Centre Universitaire Méditerranéen, where the meeting was held, and in the lobbies of Nice hotels, also centered primarily on cooperation in astronautical research activities.

The 60-man American delegation to the meeting was headed by Richard (CONTINUED ON PAGE 84)

Harold Urey (left) uses a newspaper item to emphasize his point via a translator to Anatoly A. Blagonravov.



Jack Townsend of NASA takes a gander at the various instrumentation seated in a Skylark rocket.

Hydrogen for the Space Age

Rapidly approaching, the hydrogen-oxygen rocket, a dream of the rocket pioneers, will up the payload ante in many space vehicles

By Richard J. Coar and Charles H. King Jr.

PRATT & WHITNEY AIRCRAFT FLORIDA RESEARCH AND DEVELOPMENT CENTER, UNITED, FLA.

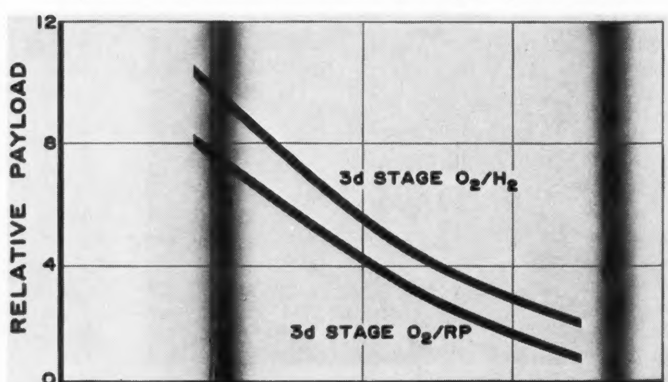
Coar King

Richard J. Coar and Charles H. King Jr. are members of the engineering team at Pratt & Whitney Aircraft's Florida Research and Development Center, Coar as chief engineer of advanced projects and King as a project engineer. Coar graduated from Tufts College in 1942 with a degree in mechanical engineering, and joined Pratt & Whitney that year as a test engineer. He holds several patents in the fields of aircraft powerplants and controls, and has been prominent in the development of some of P&WA's advanced gas turbine projects. King, who was founding President of the ARS Connecticut Valley Section, graduated from MIT in 1941, and received a master's degree in aeronautical engineering from CalTech in 1946. He joined United Aircraft's research department in 1946, and was head of the combustion section of the department before transferring to P&WA in 1958.

THE ELEMENT hydrogen has long been recognized as a rocket fuel with outstanding thermodynamic performance characteristics. Its high heat of reaction with all oxidizers, combined with the low average molecular weight of the reaction products, produces specific impulses higher than chemical systems employing any other fuels. In addition, the high diffusivity and chemical reactivity of hydrogen and its high cooling capacity simplify problems of injector and thrust-chamber design. Because the element has some less favorable characteristics, such as low boiling point (37 R) and low density (0.58 lb/gal), it is necessary to study the payload capability of actual vehicles employing this fuel to evaluate its true worth.

Perhaps the most immediate application of liquid hydrogen is in top stages on existing boosters, to improve the space payload capability. For example, when a third stage is placed on an assumed conventional two-stage vehicle, with resulting stage weight ratios of about 3, the use of hydrogen in the third stage increases the payload delivered to a 300-mile orbit by 10 per cent over that obtained with conventional propellants in the third stage. However, the hydrogen third stage delivers to a 24-hr orbit twice the payload afforded by conventional propellants in the third stage.

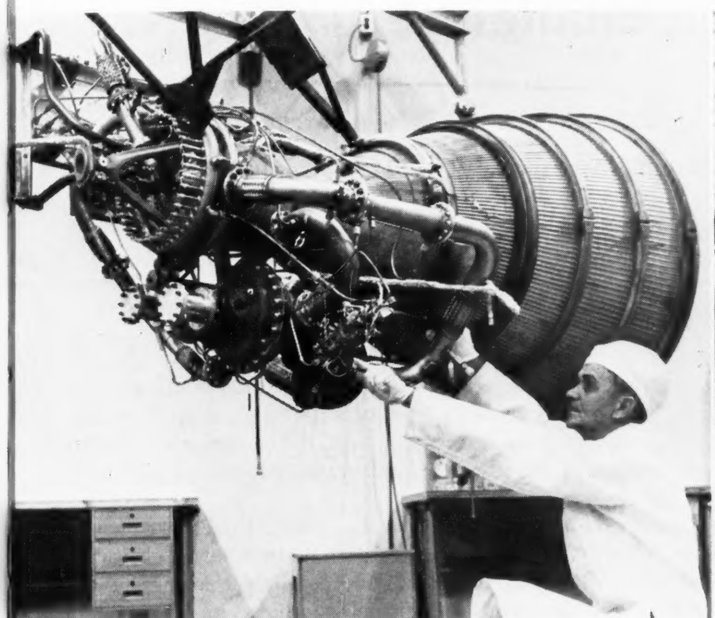
Payload Improvement with Hydrogen Third Stage

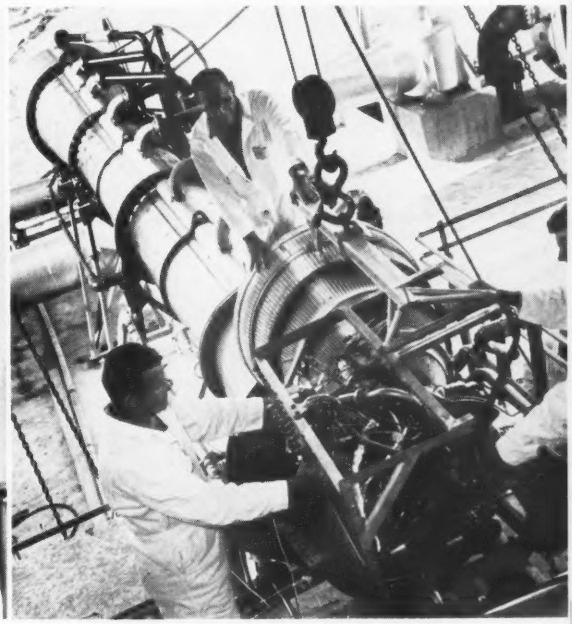


This emphasizes the payload gains possible for difficult missions by using high-energy propellants. Similarly, improvements in payload are possible when a hydrogen stage is used on top of existing single-stage vehicles. Moreover, the foregoing analysis assumed for the hydrogen stage a conservative I_{sp} of 400 sec and twice the structural fraction used with the conventional-propellant stages to compensate for the low density of liquid hydrogen.

The fact that hydrogen upper stages can increase significantly the payload placed in orbit by existing boosters has been recognized by the National Aeronautics and Space Administration in planning their space vehicle program. In its space research, NASA plans to employ hydrogen-fueled Centaur stages on the Atlas to boost a payload weighing more than 1500-lb into a 24-hr orbit. Only 750 lb of payload could be boosted into the same orbit by a conventionally fueled stage on the same booster.

Below left, the nation's first major liquid hydrogen rocket engine, the 15,000-lb-thrust XLR-115, under development by Pratt & Whitney Aircraft's Florida Research and Development Center for NASA.

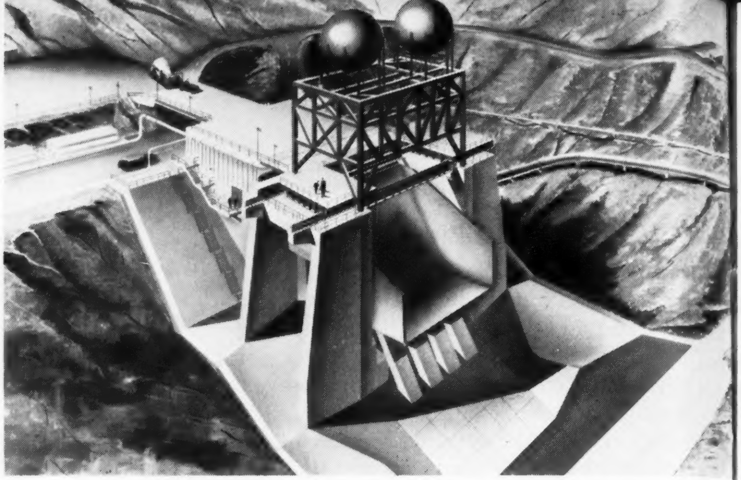




Above right, the engine is lowered onto a test stand at the development center. The long tube, into which it fires, creates a vacuum for starting operations.

Although the payload of existing boosters can be improved dramatically by using hydrogen upper stages, significant improvements in payload, or reduction in size and number of stages, are also possible by using hydrogen in all stages of a multistage vehicle, including the booster itself. For example, the payload which a 6-million-pound thrust four-stage vehicle can put into a 24-hr equatorial orbit increases from 25,000 lb, when all stages are oxygen-hydrocarbon, to 90,000 lb, if all stages are oxygen-hydrogen. It is also significant that a three-stage hydrogen-fueled vehicle will do essentially the same job as a vehicle with conventional booster and three hydrogen stages.

These payload capabilities result from specific impulses almost 40 per cent higher than those offered by conventional oxygen-hydrocarbon propellants, and this in spite of hydrogen's low density and the attendant large tank volumes. For space missions requiring higher performance, nuclear rockets are the next practical step. (CONTINUED ON PAGE 76)



An artist's view of the 6-million-lb thrust test stand, for rocket engines of the Saturn and Nova class, being built at Edwards, AFB, Calif.

Rocket test stand challenge

A problem in solution: Produce a $10-million rocket test facility that meets state-of-the-art needs without becoming obsolete overnight

By B. F. Rose Jr.

AETRON, A DIVISION OF AEROJET-GENERAL CORP., COVINA, CALIF.

Benjamin F. Rose Jr. is manager of Aetron. A graduate of the Univ. of Illinois with a degree in civil engineering and a registered mechanical and civil engineer in several states, he started his career with the Chicago Bridge and Iron Works; continued at Lockheed as chief planning engineer, responsible for integrating all prime factors essential to efficient project engineering; moved to Douglas as assistant plant manager, his work there including maintenance of production facilities and design and construction of new facilities; and finally joined Aerojet-General in 1947, where he has advanced steadily from design engineer to his present position, in which he has a major part in the direction of Aetron's work in the architectural engineering and electronic fields.

THE MOST dramatic concept of the Space Age, into which the first feeble steps have been taken, illustrates the toughest problem confronting the designer of a test facility. It is the continuously increasing acceleration of development and progress in practically every field of the physical sciences.

And rocketry utilizes every field of the physical sciences.

Capt. Edward V. Rickenbacker, Eastern Airlines board chairman, said recently: "Research into power sources, propellants, and other areas allied with the aeronautical sciences indicates that we will be able to accomplish more in the next 10 years than our industry has been able to achieve in the past 50 years of powered flight."

Again, Donald W. Douglas, Douglas Aircraft Co. board chairman, said: "It is paradoxical that most long-range predictions made in past years about aircraft development ultimately turned out to be conservative. The rate of aeronautical-design progress . . . often confounds the experts." Even these statements may be conservative.

One of the toughest problems in the rapid advance of rocketry can be defined at once: Design a 10-million-dollar test facility which will meet all the present state-of-the-art requirements *and which will not become obsolete overnight*.

In the design, development, and manufacture of rockets with their propulsion and guidance systems, achievements and objectives are strongly affected and sometimes controlled by two major factors—time and money. As clever as the rocket man may be, it is no reflection upon his ability to say that it is impossible to design and manufacture a successful rocket vehicle without exhaustive research and development testing. The complexity of the art is too great for an exclusively theoretical approach, and the costs of launching a missile

on a one-way trip to destruction before all possible information has been squeezed out of it is absolutely prohibitive.

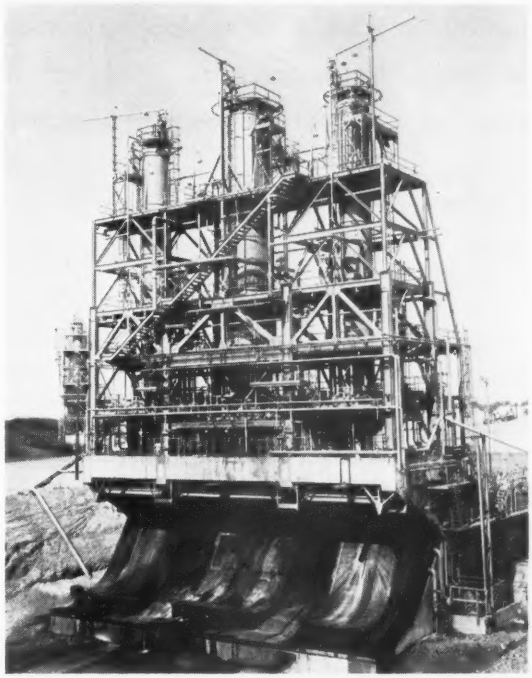
The static-testing facility has much to do with setting the pace of a rocket development program and determining its ultimate time and cost. Because we know that the development program must shift and change with the results of almost every test, the knowledge and experience utilized in the design of rocket test facilities builds into them as much flexibility for adaptation, modification, or multipurpose usage as possible.

A Thwart to Versatility

But the effort to incorporate versatility into a test facility is often thwarted by the planners who want a thus-and-so facility for a thus-and-so rocket. And in this business, while the customer is not always right, there is little room for argument. The recent and rapid trend toward greatly increased thrust, greater missile size, and unique configurations has added to the problem of versatility. However, this same trend has brought a ray of hope for cost reduction, because test and launching activities may be combined in some instances in the same facility.

In discussing the factors of test-stand design, the concept of an over-all test facility cannot be ignored. After all, a test stand is an instrument, huge though it may be—analogous perhaps to the probe of a vacuum-tube voltmeter. Through its numerous umbilical ties to the instrumentation and control station are transmitted the data which comprise the whole objective of the test. A test stand is thus a part of a complex which includes the stand, control station, propellant storage and supply facilities, water systems, power systems, disposal systems, communications systems, access roads, assembly shops, and a host of other supporting facilities.

A consideration formerly overlooked in the design and planning of a test (CONTINUED ON PAGE 78)



The modern high-thrust test stand challenges the facility's planner and engineer as he tries to keep step with rapid advances in rocketry. This high-thrust stand (above) and its master control room (below) at Aerojet-General's Liquid Rocket Plant in Sacramento, Calif., indicate the monumental size and complexity of the *instrument* which the test stand comprises.

Psycho-social problems of manned spaceflight

Analysis of work done to date on human factors indicates the need for a full-scale study of the psychological, social, and sexual behavior of spaceship crew members

By George A. Peters

DOUGLAS AIRCRAFT CO., EL SEGUNDO, CALIF.

George A. Peters, a human-factors research engineer at Douglas Aircraft, has had experience in the application of human-factors data to the engineering design of military weapons systems, both in the government service and as an industrial consultant. His six years of military service during WW II and the Korean conflict included duties as a personnel psychologist, classification and assignment officer, and construction engineer. He has done graduate work in both psychology and engineering, and has published approximately 150 articles in various scientific journals, technical publications, and books.

THERE HAS been a great deal of controversy concerning the role that man will personally play in astronautic flight. Some consider the manning of spacecraft as an expensive luxury, since they feel that man's function could be performed more economically with specially designed automatic equipment. Others describe the comparative advantages of man's ability to make unrehearsed observations and decisions, to function effectively in rather ambiguous perceptual situations, to draw upon and use an immense existing data-storage capability, and to adapt or change his mind as the circumstances dictate.

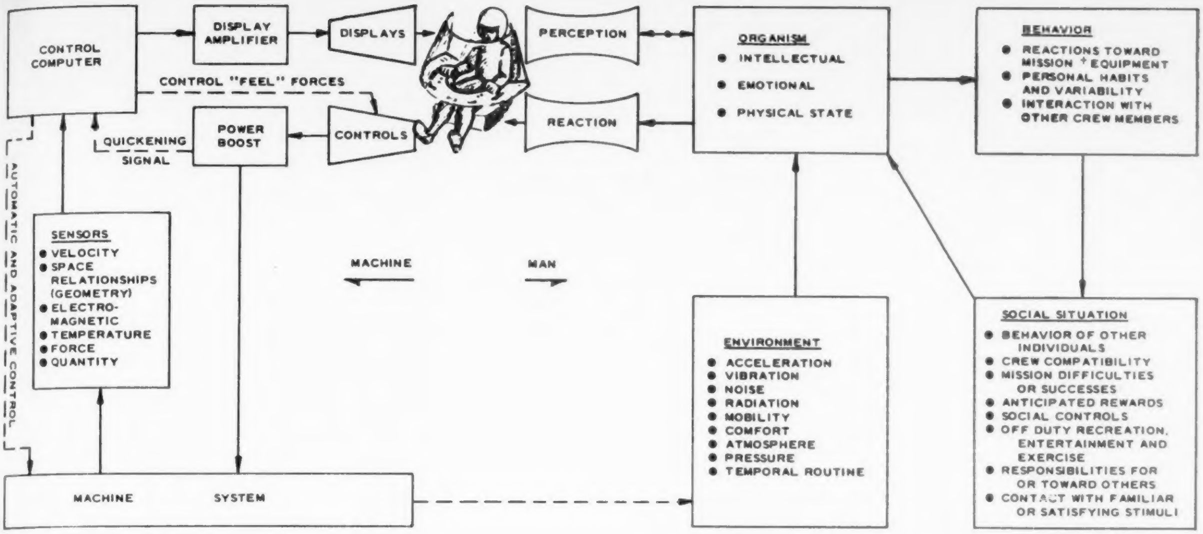
Undoubtedly, as the capability for spaceflight increases, the relative advantages of man as an integral component of the spacecraft will be utilized in some of the variety of space projects which can be envisioned. He will probably find useful roles in flight management, scientific observation, maintenance and repair, reliability override, redundancy, or adjustment functions; special tasks such as the assembly of space stations, or merely to save the weight, cost, and development time of certain complex or highly specialized equipment.

If man is to perform some useful astronautical functions, we might ask whether any unique human problems might be anticipated from man's projection into the space environment. Now and again it has been stated that no particularly insurmountable problems should be expected. However, we might ask why there is a tendency to think that the manning of space vehicles would not constitute a major problem? Perhaps it might be for these reasons.

1. There always seems to be a general tendency to overestimate man's ability to adjust and make compensations for things which are not quite optimum.

2. Human limits or tolerances are usually defined in terms of only one variable at a time (i.e., temperature, g-loadings, vibration, isolation, etc.). Research investigations typically involve the manipulation of only one variable at a time and only rarely investigate interaction effects. Such a situation is not likely to occur in spaceflight.

3. Inferences regarding human reactions to spaceflight are often made from studies on human isolation, survival, and sensory de-



Man-Machine Interaction in Manned Spaceflight

privation where the subjects know they are not facing any real danger, can stop the experiment when they wish, know what the outcome will be, have emergency aid on standby, and are not subjected to multiple stresses, or are exposed for relatively short periods. But, despite such unrealistic simulations of spaceflight conditions, the evidence from *most* of these studies is hardly optimistic in regard to human reaction to spaceflight conditions.

4. Statements regarding manned space vehicles often refer to vehicles of relatively *short* flight duration, such as first-generation maneuverable and recoverable orbital vehicles. However, the problems may be quite different for crews involved in long, uneventful spaceflights or residing for long periods in inhabited space stations (i.e., a type of close confinement with minimal environmental variety or activity). Astronauts involved in such tasks as the orbital sweeping of astronautical derelicts or active monitoring of a radio or TV satellite could, conceivably, be considered exposed to a radically different space environment—one involving close confinement and constant vigilance and activity.

It is now generally accepted that the immediate environment can markedly influence the behavior and thoughts of even the most normal individuals. This was dramatically evident in Korean War brainwashings (hsi-nao) and propaganda confessions. And we should remember that when brainwashing phenomena first occurred, military officials were quick to denounce it as an unforgivable weakness and even treason. We now know that such breakdowns can occur to various degrees in almost anyone, given the right situation.

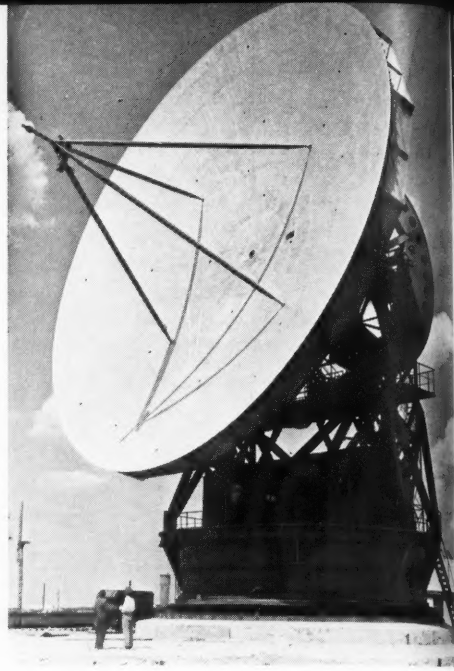
A fanciful view of chemotherapeutic control of sexual drive in manned space missions.

What Psychological Catalysts?

What are some of the precipitating factors in the space environment which could possibly induce unusual or extreme human reactions?

First we might make a general distinction. The internal environment of the space vehicle will undoubtedly remain a compromise between the psychophysiological (human) needs of the passengers and the structural or engineering requirements.

Then, any nonoptimal environmental condition imposed on a man-machine system can be interpreted as a *stress*. In the space environment there will probably be a far greater number of stresses than have ever been imposed upon man before—noise and vibration, g-loadings, "artificial" gravity or some weightlessness, ionizing radiation, fear, states of alert, close confinement over long periods, use of reclaimed water and special foods, a recycled atmosphere, odors, temperature and humidity changes, restrictions as to (CONTINUED ON PAGE 89)



The first of its kind in Russia, this 22-meter mobile radio telescope, recently completed at Lebedev Physics Institute near Moscow, will be used to study the moon, sun, and planets.

U.S.S.R.'s new radio telescope

The first maneuverable radio telescope in the Soviet Union will soon be linked with a giant one for intergalactic studies

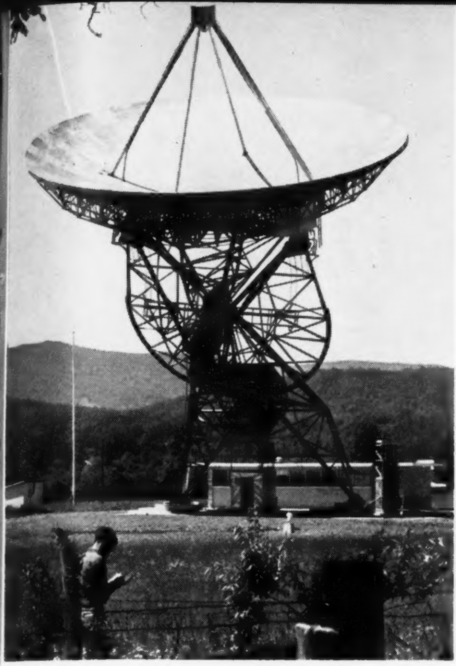
THE RADIO astronomical station of the Lebedev Physics Institute, U.S.S.R. Academy of Sciences, is a few hours ride from Moscow. There are no factories or other industrial facilities in its neighborhood. The site has deliberately been so chosen to avoid possible interference in the operation of extremely sensitive instruments.

Progress in radio astronomy calls for increasingly large radio telescopes, including adjustable types with parabolic mirror antennas, which may be solid, mesh, or trellis metal constructions whose surface reflects radio waves. There are a few large mirror radio telescopes abroad at the present time. However, all of them can only receive radio waves a few centimeters long. The largest is installed at Jodrell Bank, England.

The first telescope of the adjustable type in the Soviet Union has recently been built and is being fieldtested at the Lebedev Institute's station.

It has taken a group of the Institute's researchers, headed by Senior Researcher A. E. Salomonovich (M.Sc., physics and mathematics) and P. D. Kalachev, chief designer of the radio telescope, a few years to develop this telescope. The engineering and manufacturing side of the project was done by a number of designing (CONTINUED ON PAGE 89)

Engineers Georgy Basistov (left) and Nikolai Amenitsky man the central control board in the main cabin of the radio telescope.



Left, the National Radio Astronomy Observatory's radio telescope nestles in Deer Creek Valley near Green Bank, protected from winds and extraneous radio noise by surrounding 4000-ft-high rolling hills. Associated Universities Inc. operates NRAO for the National Science Foundation.

Billion light years into space

The range, precision, and versatility of the National Radio Astronomy Observatory's radio telescope broadens space exploration

IN RECENT MONTHS, the radio telescope has been receiving due attention as a means for space exploration. A prime example of the radio telescope in this country is the National Radio Astronomy Observatory's instrument at Green Bank, W. Va. Designed and built by Blaw-Knox Co. of Blawnox, Pa., the NRAO radio telescope features an 85-ft dish antenna and associated equipment that give it a reach into space of at least a billion light years. Refinements in its receiving equipment will extend this range possibly an order of magnitude in coming years.

The 85-ft NRAO telescope and its associated receivers has already been used to study the moon, our nearer planets, and central regions of our own galaxy, and to observe galaxies very distant from ours.

For instance, recent observations on Jupiter have shown that this planet radiates more power at wavelengths between 10- and 70-cm than can reasonably be explained by assuming that it is just a hot body. A likely explanation of the high radiation from Jupiter is that, just as on earth, there are belts of trapped high-energy particles in its outer atmosphere. These belts would have to be much larger than the earth's and contain many more particles.

Also, a detailed map has (CONTINUED ON PAGE 86)

A four-post telescopic elevator permits electronics technicians to change or repair receiving equipment in the focal point of the telescope, which for this servicing focuses on the southeastern horizon.

Making a high-thrust rocket chamber

Novel design and construction features characterize the high-thrust liquid rocket chamber developed by NASA's Lewis Research Center

As part of its program to advance the state of the art of liquid rocket engines for space vehicles, NASA's Lewis Research Center, and in particular the Rocket Engines Branch headed by John L. Sloop, some time ago conceived and designed a novel thrust chamber that promised to be extremely light for its size and strength and to provide exceptional design flexibility with high-energy propellants. Solar Aircraft Co. of San Diego, Calif., is now manufacturing this chamber, applying and developing new approaches to fabrication and materials demanded by the design.

The design concept involves a large number (180) of parallel regenerative-cooling channels running from a central fuel manifold at the chamber neck down to the extremity of the nozzle skirt and then back up through the same number of channels to the injector head. The channels are of sheet metal, yet they allow precise control of coolant area.

Designed for a thrust range of 13,000 to 20,000 lb, the chamber as presently manufactured weighs about 90 lb and stands about 5 ft high, measuring 39 in. in diam at the skirt, 7.8 in. at the throat, and 10.5 in. at the head.

The fabrication techniques that have made this chamber possible are interesting. Moreover, in the course of work on the chambers, numerous advancements have been made in the areas of precision component forming, assembly methods, electrogrinding, ribbon forming, stretch wrapping, and spacer buildup. Interesting new applications are being made in multiple brazing techniques and cycling.

Fabrication Procedure

In fabricating the chambers, 360 straight strips of 0.008 in. AM350 stainless-steel sheet are blanked out and then formed and sized into a "U" channel in one operation on a one-piece die representing the angular segment of the engine.

Following this operation, 180 of these channels are assembled on a stainless-steel mandrel that has

Far left, racking U-channels on design-shaped mandrel. Left, applying some of the 100,000 spot welds, which go on in a specific pattern to insure close fit and dimensional tolerances.

Following grinding, on same lathe, ribbon-wrap and copper brazing alloy are fed in strips onto the turning chamber.

been cast and machine-contoured to the desired chamber configuration. Then, 180 more channels are joined piggyback at the neck of the hourglass-shaped chamber and gradually fed into a skirt with the other 180.

The channels are racked, with the open side facing out, through the use of notched clamping devices, and then are joined with approximately 100,000 spot welds. The welds are easily and quickly applied in a specific pattern to insure close fit-up and hold dimensional and configuration requirements. The assembly is annealed in a hydrogen atmosphere to hot-size the channels to the exact shape of the mandrel. The channels are then sized and electroground on a special lathe to specified heights along the entire chamber length. This precision grinding provides the accurate coolant-passage geometry necessary to the design concept.

Following the grinding, while still on the lathe, the chamber is wrapped tightly with approximately 2650 ft of 0.008 in. AM350 stainless-steel ribbon. This ribbon, along with a copper brazing ribbon, is fed automatically around the chamber from a spool geared to the revolutions of the lathe.

External Sealing

Following the wrapping, additional copper braze filler is sprayed onto the chamber to provide external sealing of interlocked ribbons. The chamber is then ready for brazing, which will integrate the wrapping and channels into tubelike fuel passages.

A large, 600-kw elevator-type furnace with multiple zone control is used for the brazing operation. This is done in a welded (CONTINUED ON PAGE 44)

At right, the wrapped assembly is sprayed with additional copper brazing filler to provide an external seal on the interlocked ribbons. Far right, the chamber emerges from Solar Aircraft furnace at end of the brazing cycle.

Fuel cells for space vehicles

The closed-cycle, regenerative fuel cell shows potential as a long-running, high-efficiency power source for space applications

By M. G. Del Duca, J. M. Fuscoe, and T. A. Johnston

THOMPSON RAMO WOOLDRIDGE, INC., CLEVELAND, OHIO

M. G. Del Duca, a member of TRW's Advanced Systems Analysis Group, received a B.S. from the Univ. of Notre Dame in 1950 and a Ph.D. in physics from Western Reserve Univ. in 1956. From 1956–58, when he joined TRW, Dr. Del Duca was an aeronautical research scientist with NACA, where his work included theoretical and experimental research in mechanics of solids and ionic phenomena associated with the upper atmosphere.

J. M. Fuscoe is Systems Engineer for the development of a regenerative fuel-cell system at TRW, where he has also worked on solid-propellant APU's, liquid-metal heat transfer, change-of-phase energy storage, and high-temperature insulators. Previously, after receiving a B.S. in chemical engineering from North Carolina State College and serving in the Army as an electronics and radar instructor, he did rocket engine system analysis at Rocketdyne.

T. A. Johnston joined TRW in 1950 after receiving a B.S. in chemical engineering from Case Institute of Technology, and in 1959 became head of the Space Power Systems Group of its Research and Engineering Requirements Dept. His background includes various work on fuels and nuclear reactors. In 1956 he worked for the Gilbert Tramer Co. on the design of special chemical processing equipment, and he is a 1958 graduate of the Oak Ridge School of Reactor Technology.

MANY PROBLEMS still remain to be solved before interplanetary space exploration becomes a reality. One problem is the development of efficient, low-weight electric power units to drive subsystems in space vehicles. There are many types of indirect and direct conversion units for generation of electric power. We are primarily concerned here with one type of direct conversion unit, the fuel cell.

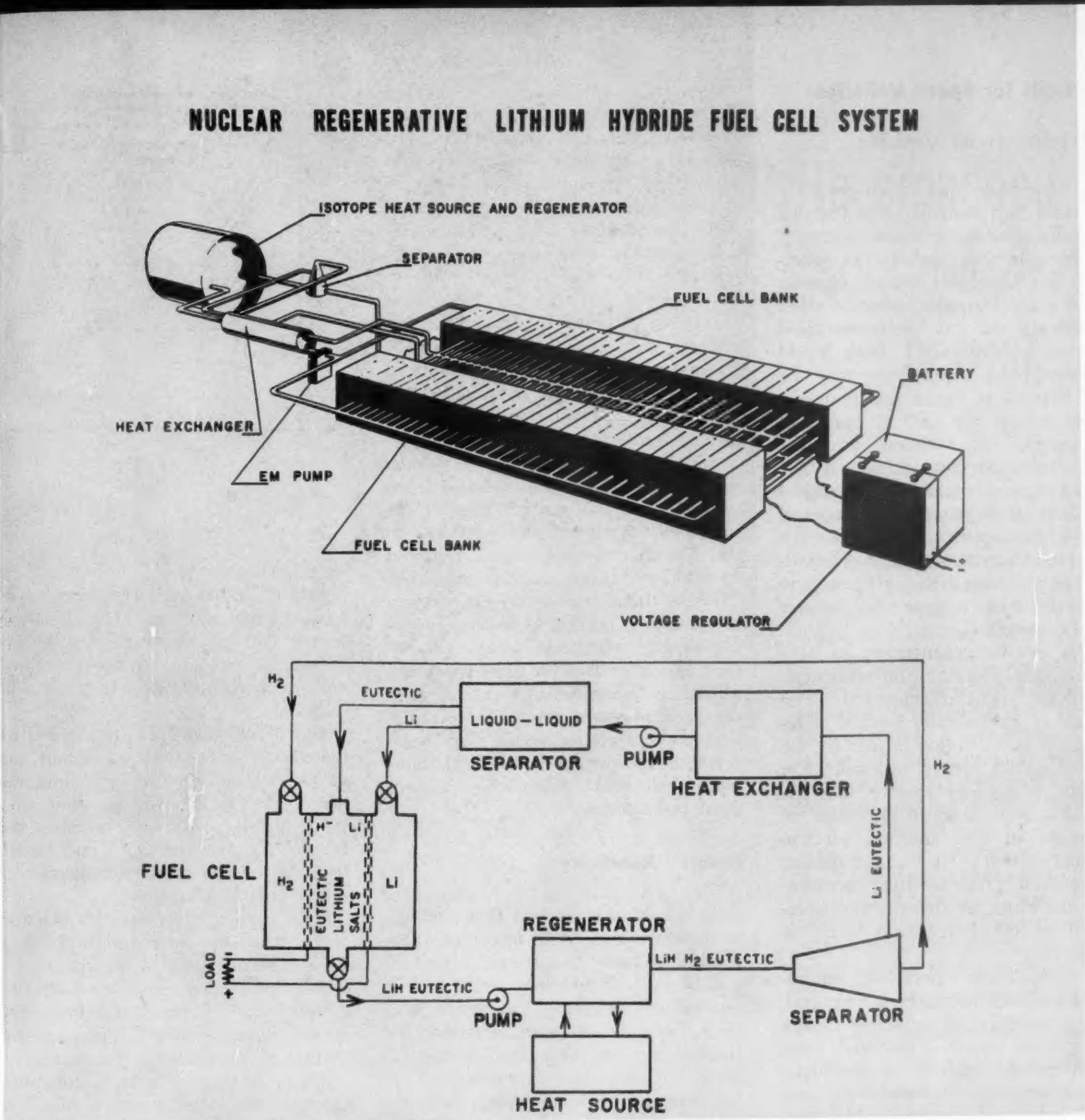
A fuel cell is a device which converts chemical to electrical energy. It differs from the common battery in that the cell reactants are not stored within the cell but are continuously fed to the cell from the outside. The products of the electrochemical reactions occurring within the cell may easily be collected and regenerated by addition of energy from some external source. The regenerated reactants can then be recycled to the fuel cell, thus giving a closed-cycle system.

The closed-cycle fuel cell shows great potential as a long-duration, high-efficiency power generating system for space applications. In particular, a nuclear regenerative fuel-cell system for small powers looks attractive, since it may meet other requirements for space systems, e.g., low specific weight and volume.

Dynamics of the Fuel-Cell System

To begin, let's look at a fuel-cell system, as shown schematically for instance at the top of the opposite page, with the reactants a liquid metal and a gas. The gas and liquid metal react in the cell (eutectic of the metal salts as electrolyte), releasing heat and generating a potential across the metal and gas electrodes. The reaction products disperse in the electrolyte, and this mixture is pumped into a decomposition chamber where the products are dissociated to the reactant fuels by application of energy from an external source. The reactants and the electrolyte, on leaving the dissociation chamber, enter a separator where the gas is separated from the regenerated fuel-electrolyte mixture. The metal-electrolyte mixture is subsequently cooled to cell operating temperature by cycling through a suitable heat exchanger and then pumped through a liquid separator. Liquid metal, electrolyte, and gas are then separately recycled through the cell.

The basic components required in a regenerative, closed-cycle power conversion unit utilizing an electrochemical fuel cell must thus include a fuel cell, energy source for regeneration, dissociation chamber (regeneration of react- (CONTINUED ON PAGE 38)



Components and Characteristics

For a 550-Watt, 28-V Performance on 11 Percent Thermal-Electric Conversion Efficiency

Fuel Cell	
Electrolyte	lithium chloride-lithium fluoride eutectic
Total weight (dry)	120 lb
Total weight (with cooling fluids)	158 lb
Volume	720 cu in.
Open circuit voltage	0.6 v
Operating cell voltage	0.45 v
Heat rejection	6700 Btu/hr
Surface area	95 sq in.
Operating temperature	500 C
Flow Rates of Constituents into Cell:	
Lithium	0.7 lb/hr
Hydrogen	0.1 lb/hr
Electrolyte	14 lb/hr
Energy and Source and Fuel Regeneration Chamber	
Isotope	cerium-144
Heat supplied to dissociation chamber	10,800 Btu/hr
Estimated cost of isotope	$950,000/yr
Weight of energy source	56 lb
Size of energy source	4 in. daim – 8 in. diam
Fuel regeneration temperature	850 C
Flow rate into fuel regeneration chamber	14.8 lb/hr
Heat Exchanger	
Type	concentric tube counterflow arrangement
Outside tube diameter	1/4 in.
Inside tube diameter	1/16 in.
Effectiveness	96 percent
Outlet temperature	836 C
Weight	0.6 lb
Pump	
Type	electromagnetic
Weight	8 lb
Controls	
Type	voltage regulator
Weight	20 lb
Separator	
Type	centrifugal
Weight	1 lb

Fuel Cells for Space Vehicles

(CONTINUED FROM PAGE 36)

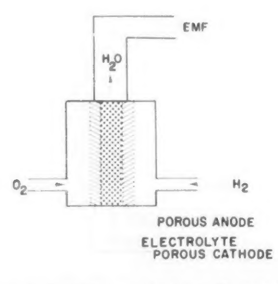
ants), separators, heat exchanger and/or radiator, and controls. The fuel cell may utilize gaseous or liquid reactants. Hydrox cells (H_2 and O_2 as reactants), for example, utilize gaseous fuels at both electrodes, whereas other cells consist of gas electrode-liquid electrode combinations. Both liquid and fused-solid electrolytes may be used, depending upon the temperature at which the cell is operated, the specific cell reaction, and the physical state of the reactants.

Since electrochemical reactions produce heat, it is necessary to control fuel-cell temperature. This may be accomplished by designing a cell with sufficient radiative area. However, in certain systems a separate radiator must be provided.

Fuels can be regenerated by several methods—thermal, photochemical, electrolytic, and radiochemical. The selection of an optimum method of regeneration is controlled in part by the electrochemical system utilized. For example, a nuclear reactor may be used as a heat source if optimum regeneration of the selected electrochemical system is by thermal means. (In nuclear regenerative systems, either quantum or thermal regeneration of chemical reactants may be considered.)

In closed-cycle operation, separation of fuel-cell products is required, and the selection of separator design for a specific system is obviously controlled by the nature of products. Thus, separators to be considered may be liquid-liquid, solid-liquid, gas-liquid, gas-gas, gas-solid, or solid-solid, again depending on the specific system. Choice of a regenerative closed-cycle system must consider both the chemical and physical properties of the reactants and products; and particular emphasis must be placed upon the separability of components, since the efficiency of the closed-cycle system is obviously related to this parameter.

SCHEMATIC OF A HYDROX FUEL CELL



Since the cell potential is a direct function of temperature, concentration of fuels at the electrode, and the internal resistance, controls must regulate output, provide optimum flow of reactants to electrodes, and reduce cell temperature fluctuation. In selecting and optimizing regenerative fuel-cell systems for space vehicles, many factors must be taken into consideration which are of little or no importance for earthbound applications. Paramount among these considerations are system weight, reliability, and space environment, the last particularly as it affects weight and reliability.

In most regenerative systems, the significant weights will be associated with the fuel cell itself. This weight in general is directly proportional to the limiting electrode area required to achieve the necessary power level. Thus, systems which have inherently low limiting current densities, resulting in high electrode areas, will appear less attractive for most space applications. Similarly, since all heat rejection in space must be by radiation, those systems having high heat-rejection temperatures and high thermal-to-electrical efficiencies appear most promising.

Favored Reactants

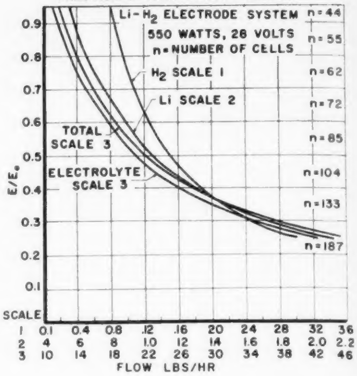
In considering system flow and inventory weights, it is apparent from Faraday's Law that those reactants will be favored which have the lowest equivalent weights. For space systems, specific volumes are directly translatable to skin and structure weights. Also, limitations in packaging densities for each system must be given consideration.

Assuming that maintenance of space systems will not be feasible during operation, the selection of components and reactants must be made to assure maximum reliability. Of prime importance, then, are reactants and electrolytes which have acceptable noncorrosive properties. Complexity may eliminate many fuel-cell systems involving dual cycles, since these types pose sensitive control situations. Similarly, in the fuel cell itself simplicity of cell electrochemistry and reactant regeneration favor the selection of simple ionic reactants.

Reliability considerations dictate selection of those systems having a minimum number of parts subject to wear, fatigue, or seizing. Where possible, therefore, selection of components having no moving parts and hermetically sealed systems are to be preferred.

For satellite applications, variations in vehicle skin temperature will occur due to the space environment. These must be taken into consideration in

FUEL FLOW REQUIREMENTS VS FRACTION OF OPEN CIRCUIT VOLTAGE



heat-balance system design. It is highly desirable to incorporate a control system that enables the heat source and power conversion system to seek a constant temperature level and temperature gradient for the package.

For a fuel cell operating under reduced- or zero-gravity conditions, numerous other problem areas must be taken into consideration—sealing, electrode reaction, electrode interface stability, fluid-condensing and heat-transfer characteristics, transport of fluids, polarization, etc.

The starting procedure for the fuel cell unit is a separate design problem. Orbital starting would incorporate remotely controlled or delayed starting techniques. Ground starting and launch conditions will influence the ability of the fuel-cell power unit to operate during vehicle acceleration through the atmosphere. Acceleration will introduce additional g-loads on the entire system. Orientation of the system to withstand required longitudinal and transverse loading as well as vibration, etc. must be incorporated early in a system design. During launching, the aerodynamic conditions may cause a wide variation in critical component temperature; for example, that of the radiator, which, if not controlled, could be detrimental to the cycle and fuel-cell system operation. To reduce transient phenomena and simplify the system control, it may be desirable to limit pressures and temperatures to the neighborhood of the design values.

These are merely a few of the special considerations affecting the design of regenerative fuel cells for space vehicles. Let us now turn to a more detailed analysis of each component and its associated problem areas.

In the fuel cell itself, the chemical energy associated with the reaction of fuels is not first degraded to heat as in heat engines; therefore, fuel cells

are not restricted by Carnot-cycle efficiencies.

The table below lists various electrode systems, several of which can be utilized in fuel cells for space vehicles.

ELECTRODE SYSTEMS	EXAMPLE
Metal, metal ion	Cu, Cu^{++}
Inert electrode, nonmetal in solution, ion	Platinum, I_2, I—
Inert electrode, ions of different valence	Platinum, Fe^{+++}, Fe^{++}
Inert electrode, gas, ion	Graphite, H_2, H^+
Inert electrode, neutral solution in different states of oxidation	Graphite, $C_6H_4(OH)_2$
Amalgam electrode, ion	(Cd Hg), Cd^{++}
Electrode, insoluble salt or oxide, ion	Ag, AgCl, Cl—

One specific system with space application is the hydrox cell. This cell, diagramed on page 38, utilizes an electrode system of the inert electrode-gas-ion type and hydrogen and oxygen gases as reactants. Oxygen and hydrogen gas are fed through porous electrodes to the electrolyte-electrode interface where the reaction occurs. The water formed in the electrolyte must be removed in a closed-cycle operation. The reactants, H_2 and O_2, can be regenerated by either thermal or quantum energy. Also, electrolytic regeneration is possible, even though this method is highly inefficient.

Choice of Energy

The choice of the type of external energy source in closed-cycle systems is controlled by the particular cell reaction utilized in the cycle. The reaction between lithium and hydrogen, for example, shows great potential in closed-cycle systems where the external source is thermal.

This system suggests the use of a nuclear heat source to regenerate the lithium and hydrogen. For long operating times, the nuclear reactor and radioisotopes both appear attractive. The type of reactor for this application must be compact, lightweight, and capable of high-temperature operation. The requirement of high-temperature operation is necessitated by the heat sink, which rejects heat by radiation, and by the high-temperature requirements of the fuel cell. Furthermore, the reactor should be reliable enough to function through the life of the mission. Energy sources required for radiochemical regeneration have received only limited considerations by investigators because of the low efficiencies associated with these processes. (Rosenblum of NASA has considered the use of a hydrox fuel cell with a radioactive isotope, such as the alpha emitter $P_o^{210}(t^1/_2 = 138$ days), as the energy source.) Photochemical and electrolytic energy sources have received some attention, but they are limited by low efficiencies.

The utilization of a heat exchanger in a closed-cycle fuel-cell system operating with cell temperatures appreciably less than the dissociation temperature is a very attractive possibility. For systems utilizing working fluids with high heat-transfer coefficients, almost complete heat exchange can take place with very little penalty in weight. This will result in lowering power requirements for the heat source, since the heat transferred in the heat exchanger can be utilized to further regenerate cell reactants.

The heat exchanger can be an array of concentric tubes arranged for counterflow. This is generally applicable where liquid-liquid heat-transfer systems are involved and high heat-transfer coefficients are available. For gas-gas or gas-liquid systems, heat-transfer coefficients are small, and large-area, compact heat-exchanger designs should be employed.

The design of the regenerator must consider the kinetics of the dissociation of the cell products. Thus, consideration of temperature, pressure, catalytic activity of materials utilized and most effective geometries must be taken into account. The interdependence of the dissociation kinetics with the choice of the specific energy source used for regeneration is readily evident.

To minimize the system total volume and weight, it is desirable to have the regenerator serve as an integral part of the energy source. With nuclear reactors, however, the integral arrangement may not be feasible if the required regenerator materials have high nuclear cross-sections or introduce instability problems in the reactor kinetics. Then the use of an externally cooled reactor system may be required.

The regenerated fuels must be separated for individual feeding to the cell electrodes. In general, any type of physical or chemical separation may be involved. For example, in a system using a liquid metal and a gas as fuels, with liquid metal electrolytes, two types of separations are required:

1. A separation of gas fuel from the liquid metal fuel-electrolyte mixture.

2. A separation of the metal fuel from the electrolyte.

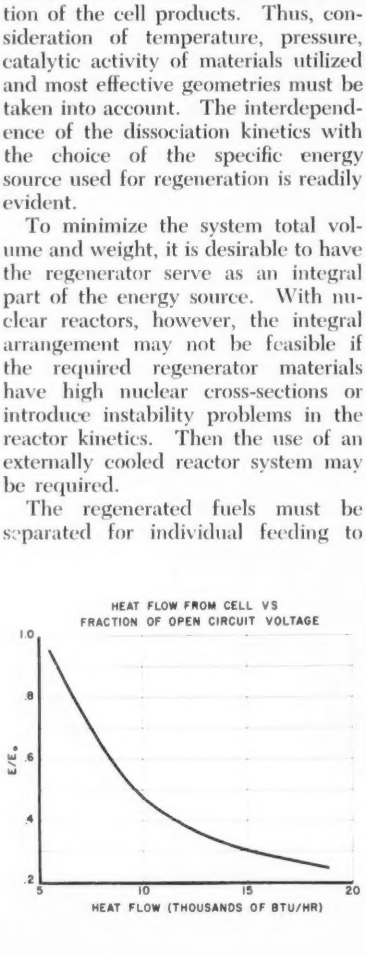
Both separations can be accomplished in one small, compact centrifugal gas-liquid-liquid separator. Such a separator consists of a cylinder in which the liquid-gas mixture is introduced tangentially at a high velocity. A conical chamber is located beneath the cylindrical section. The gas is removed from the base of the cone, the heavier liquid is removed from the side, and the lighter liquid is removed from the apex. Spiral vanes should be included in this design for zero-g operating conditions. Special separator designs must be considered, depending upon the physical and chemical states of the fuels and electrolytes.

Operation in Zero-g

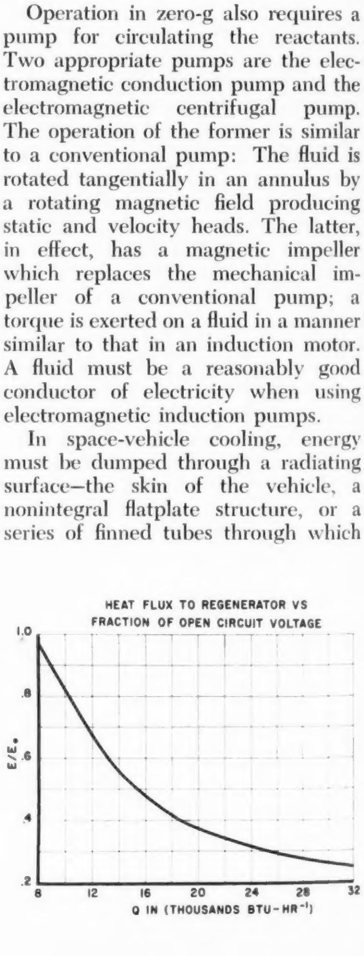
Operation in zero-g also requires a pump for circulating the reactants. Two appropriate pumps are the electromagnetic conduction pump and the electromagnetic centrifugal pump. The operation of the former is similar to a conventional pump: The fluid is rotated tangentially in an annulus by a rotating magnetic field producing static and velocity heads. The latter, in effect, has a magnetic impeller which replaces the mechanical impeller of a conventional pump; a torque is exerted on a fluid in a manner similar to that in an induction motor. A fluid must be a reasonably good conductor of electricity when using electromagnetic induction pumps.

In space-vehicle cooling, energy must be dumped through a radiating surface—the skin of the vehicle, a nonintegral flatplate structure, or a series of finned tubes through which

HEAT FLOW FROM CELL VS FRACTION OF OPEN CIRCUIT VOLTAGE



HEAT FLUX TO REGENERATOR VS FRACTION OF OPEN CIRCUIT VOLTAGE



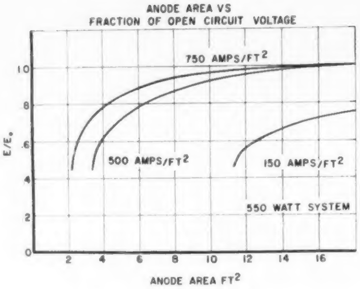
coolant is circulated. In addition to rejecting waste heat, the radiators must also reradiate the incident energy from the sun, earth, and space. The energy incident on the radiating surface depends primarily on the physical orientation of the radiator with respect to the sun and planets and the absorptivity of the radiating surface.

Next, with respect to controls, their purpose is twofold: To insure that the fuel cell supplies the required power at the specified voltage level, and does not operate at power densities above those considered safe, regardless of the external load.

The method chosen to regulate power output and voltage is controlled in part by the specific fuel-cell system and the external energy source utilized for regeneration of reactants. For example, with a Cerium-144 isotope as a heat source, the power generated will vary with time as $P = P_0 e^{-2.39 \times 10^{-3} t}$, where P_0 = initial power and P = power after t days. Since the voltage and power output of the fuel-cell system will vary with the rate at which fuel is supplied to the electrode system, it is evident that the thermal-power output of the energy source will have to be controlled. To insure safe operation of fuel cells, storage-battery technique can be utilized to meet peak-power demands. Also, parasitic devices may be employed to maintain a constant load on the cell when power demands are reduced.

Corrosion a Key

Finally, corrosion is of prime importance to fuel-cell reliability and performance. Because of the fairly large temperature gradients which may exist, mass transfer can exist concurrently with intergranular attack, alloy type of attack, preferential leaching of one alloying element, and the

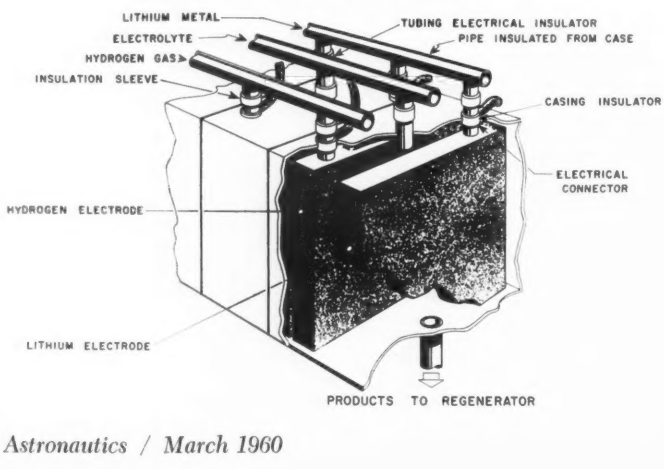


removal of impurities in alloys serving as strengthening agents. Mass transfer can cause failure by plugging tubes in low-temperature areas of the system. This will be particularly severe if the tubes are small in diameter, such as those which exist in the heat exchangers of some systems. Since mass transfer will be enhanced in those systems constructed with more than one metal, the use of a one-component metal-piping system appears more desirable in preventing this type of mass transfer.

Now, a brief analysis will give some feeling for systems design. Referring to the diagram of the nuclear regenerative fuel-cell on page 37 as a representative system, the specific requirements of the system might be given as follows:

1. Final cell reaction: $Li + {}^1/_2 H_2 \rightarrow LiH$ (electrolyte, eutectic mixture of lithium salts).
2. Electrical output: 550 watts.
3. Operating voltage: 28 v.
4. Open circuit voltage of fuel cell, E_0: 0.6 v.
5. Fuel-regeneration chamber operating temperature: 850 C.
6. Fuel-cell temperature: 500 C.
7. Energy source for regeneration of fuels: nuclear reactor.

CONCEPTUAL DESIGN OF FUEL BANK



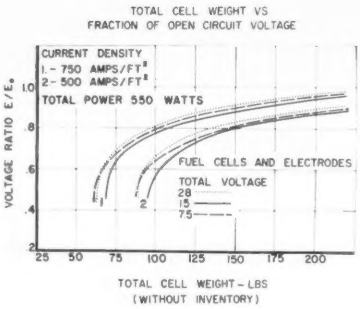
The required feed rates of the reactants to the electrodes of the fuel cells must be determined in order to establish the heat input requirements from the nuclear reactor to the regenerator; the fuel-cell radiation areas required; regenerator design configuration; nuclear-fuel requirements; and pumping speed.

For a constant power output, the required fuel-flow to the cell electrodes varies with both cell operating voltage and current efficiency of the electrode system. The graph on page 38 shows the fuel-flow requirements (corrected for current efficiency variations) as a function of cell operating voltage. Curves 1 and 2 give the flow requirement of the reactants—lithium metal and hydrogen gas. Curve 4 gives the flow of the eutectic electrolyte, and Curve 3 gives the total system flow requirement. The number of cells required to produce a power output of 550 watts and 28 v at a particular cell operating voltage is indicated.

Fuel-Cell Heat

The heat produced by the electrochemical reaction occurring in the fuel cell operating at 500 C is shown in the left graph on page 40. Operating at half-open circuit voltage, the heat which must be rejected from the cell in order to maintain constant temperature is on the order of 10,000 Btu/hr. With the use of a heat exchanger, the heat input into the fuel regenerator can be limited to just that required for dissociation of the fuel-cell products. The steady-state thermal input to the regenerator to dissociate only the lithium hydride produced in the fuel cell at different operating cell voltages is presented in the right graph; the heat inputs do not include startup heats or the heat required to increase the temperature of the cell products and electrolyte from cell temperature to regenerator chamber temperatures. The rate at which heat is transferred from regenerated fuels to the heat exchanger increases with decreasing operating cell voltages; 95 per cent of the heat transferred in the heat exchanger may be recovered. This heat is utilized to increase the temperature of the cell products before they enter the fuel regenerator.

One important criterion of fuel-cell weight is the current density (current flow per unit area of electrode surface) of the electrode system. For the lithium-hydride system, for example, limiting current densities at $^1/_2$ open circuit voltage of approximately 500 amp/ft² have been attained. Theoretical predictions indi-



cate systems can be developed with much higher current densities. High-current-density electrode systems, which utilize light materials, will greatly aid development of the maximum potential which fuel cells show for space applications.

The current density of a cell is a function of the operating voltage. Therefore, the electrode surface area (the reciprocal of the current density) and cell weight will also be a function of the operating voltage. For a 550-watt system with limiting current densities at $^1/_2$ open circuit voltage (150, 500, 750 amp/ft^2) and total system voltages of 28, 15, 7.5 v, the following cell characteristics have been evaluated as a function of operating cell voltage—required electrode area, weight per cell, and total cell weight for the system.

Anode Area

The graph on page 42 shows the anode area required for a 550-watt system at various cell voltage ratios E/E_0 with limiting current density as a parameter. The configuration shown on page 42 was used to determine cell weight. (Optimization of weight and maximum area obtainable from a cylindrical configuration were not considered at this time.) The assumptions made in the cell construction are as follows: Anode-cathode spacing, 0.375 in.; hydrogen cathode width (sintered niobium), 0.0625 in.; lithium anode width (sintered niobium), 0.125 in.; over-all cell thickness, 0.937 in.; and cell shell of 0.0265 in. molybdenum-clad stainless steel having a density of 0.304 lb/in^3.

The graph above left summarizes estimates of total cell weight, as a function of operating cell voltage, for different system operating voltages and various limiting current densities.

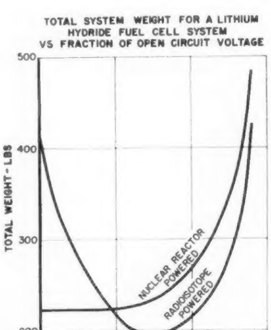
Knowing the heat dissipated per cell, the number of cells and the physical dimensions of the cells, the radiation area can be determined. The area can be varied by proper packaging.

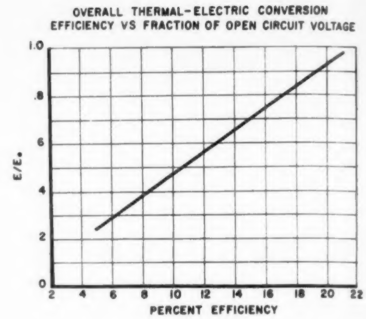
The heat exchanger system preheats the fluid entering the reactor. The structural analysis of such a system depends upon the system's flow rate, cell operating temperature, and reactor dissociation temperature. For this analysis, the fuel-cell operating temperature is set at 500 C and the dissociation temperature at 850 C. The recirculation flow enters the heat exchanger at 500 C and returns to the reactor at 836 C, while the products leave the heat exchanger at 514 C. The construction material is niobium. It can be shown that the weight requirements are negligible for a heat exchanger in a 550-watt, 28-v system with a limiting current density of 500 amp/ft^2 (at $^1/_2$ open circuit voltage) for E/E_0 between 0.25 and 1.

Weight Variation

Study of the present system shows that the only components which vary in weight to any extent with operating cell voltages are the fuel cells and a radioisotope energy source used for regeneration of cell products. If a nuclear reactor is considered, its weights are almost constant with changes in voltage characteristics of the fuel cell.

The graph shown below presents the total weight of the lithium-hydride system, including inventory as a function of the ratio of the cell voltage to open circuit voltage for both nuclear reactor- and radioisotope-powered units. For the radioisotope-powered system, the optimum value of E/E_0 for minimum weight is approximately 0.625 (E_0 for this fuel cell is 0.6 v). However, from the standpoint of cost and reliability, studies show it is advisable to operate at a value of E/E_0 of 0.75, for which only a small penalty in total system weight is paid. For the nuclear-reactor-powered system, it is recommended that the cells in the system operate at E/E_0 of 0.65, since a very small weight penalty is paid for a reasonably large increase in re-





liability. The diagram above shows the over-all thermal-electric conversion efficiency for the 550-watt, 28-v system.

The conceptual design shown on page 37 summarizes the thinking in this study. The 216-lb system, utilizing lithium metal and hydrogen as fuels and a radioisotope energy source, shows a constant power output of 550 watts at 28 v with an over-all thermal-electric conversion efficiency of 11 per cent. The table shown with the design summarizes components and their characteristics. ♦♦

Making High-Thrust Chamber

(CONTINUED FROM PAGE 35)

muffle with controlled argon or hydrogen atmosphere. In the brazing cycle, the chamber is taken above 1980 F in about 1 hr.

After brazing, the chamber is slowly furnace-cooled to 1800 F to allow unstressed solidification; then it is removed from the furnace and air-cooled to room temperature. Protective atmosphere is maintained to insure a clean assembly.

Multiple brazing techniques developed by Solar are used in the next step. Hardware attachments such as fuel manifold, reinforcing rings, and injector flange are fitted to the chamber and the second braze operation, involving a copper-tin brazing alloy, begins. This takes place at approximately 1875 F.

The chamber is then machined to mate the injector and engine mount, and the assembly is heat-treated as necessary to achieve the desired metallurgical properties of precipitation hardened AM350. This is done in a split cycle of −100 F for 3 hr followed by 3 hr at 1000 F. The chamber then undergoes a series of tests, including leak pressure using 200-psi helium in the fuel passages while the chamber is submerged in a water tank. ♦♦

ASTRONAUTICS Data Sheet — *Propellants*

Compiled by Stanley Sarner

Flight Propulsion Laboratory Dept.

General Electric Co., Cincinnati 15, Ohio

OXYGEN (O_2)

Liquid oxygen is odorless, and pale blue in color. The gas is both colorless and odorless. Oxygen has been the workhorse oxidizer for use in rocket engines for many years. It has the advantage of being cheap and readily available as well as nontoxic, but it is not storable. It yields high performance exceeded in most cases only by fluorine and ozone.

Hazards

Oxygen is, of course, nontoxic and does not form toxic decomposition products nor dangerous combustion products. Spillage is troublesome only because the low temperature of the liquid can cause serious "burns" on contact with skin.

An abundance of oxygen in the area can be dangerous due to the lowering of the flash, fire, and autoignition points, and the widening of the explosive limits of other compounds. Oxygen in contact with many materials may present an explosive hazard due to impact sensitivity and new materials should be screened before use.

Materials for Handling

While liquid oxygen is noncorrosive, many materials become brittle at the low temperatures involved and lose strength. For this reason, carbon steel, iron, and plastics should be avoided. Metals suitable for use are, in the order of increasing brittleness: Pure nickel, monel, inconel, copper, aluminum, 18-8 low carbon stainless steel, and annealed brass. Copper tubing may be used for piping, and joined with conventional brass flare fittings in small sizes or copper "sweat fittings" assembled with silver solder in larger sizes. Where weight is a consideration, aluminum or stainless-steel pipes assembled by welding may be used. Flexible metal hose with external metal braid is also satisfactory.

No lubricant can be unqualifiedly recommended and liquid oxygen might well be left to act as its own lubricant. Some lubricants found fairly satisfactory are Electrofilm, Molykote, Motor Mica, and Fluorolube. Satisfactory packing and gasketing materials are asbestos, asbestos-braided rope, paper, polyethylene, Teflon, Kel-F, neoprene, or butyl rubber. Teflon is also satisfactory as a piping or tubing material. For pipe joints, Oxyseal, waterglass cements, and a mixture of Fluorolube, molybdenum disulfide, and powdered lead can be used. Paint is a satisfactory protective coating. Due to the possibility of explosion, lampblack, hydrocarbons, grease, cotton, wool, wood, and other organic materials should be avoided.

Cost and Availability

Liquid oxygen is available in unlimited quantities for immediate shipment at a cost which varies with quantity from 1.8 to 11.4 cents/lb.

Table 1 Physical Properties of Oxygen

Boiling Point	−183.0 C	−297.4 F
Freezing Point	−218.8 C	−361.8 F
Critical Temperature	−118.8 C	−181.8 F
Critical Pressure	49.7 atm	7304 psia
Liquid Density at Boiling Point	1.144 g/cm³	71.42 lb/ft³
Viscosity at Boiling Point	0.190 centipoise	0.000128 lb/ft sec
Thermal Conductivity (−288 to −340 F)	—	0.12 Btu/ft hr F

Vapor Pressure: $$\log \frac{P}{760} \text{ (mm)} = 5.2365 + \frac{419.31}{T} - 0.00648\,T$$

Table 2 Chemical Properties of Oxygen

Heat of Formation (liquid) at Boiling Point	−3.109 kcal/mole
Heat of Vaporization at Boiling Point	1.630 kcal/mole
Heat of Fusion at Fusion Point	0.1065 kcal/mole
Heat Capacity at Boiling Point	12.99 cal/mole C

Table 3 Theoretical Performance of Oxygen*

Fuel	Specific Impulse (sec) Frozen Flow	Specific Impulse (sec) Equilibrium Flow	Chamber Temperature** (Deg K)
RP-1	286	300	3672
UDMH	295	310	3594
N_2H_4	301	313	3400
NH_3	285	294	3089
92.5% C_2H_5OH	274	287	3389
H_2	388	391	2997

* P_c = 1000 psia; P_e = 1 atm; Optimum O/F ratio.

** Corresponds to equilibrium flow impulse.

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CUT ALONG THIS LINE

Radio Interferometry

(CONTINUED FROM PAGE 24)

equivalent to saying that he permits these weak signals to accumulate over several seconds in order to deliver a recognizable amount of radio energy. But the requirement of receiving within a frequency band less than 1 cps a signal which has been Doppler-shifted by as much as 100,000 cps constitutes the essential technical difficulty alluded to above.

In principle, the solution of this difficulty requires that a continuous-wave signal be emitted by the ground station for the sole purpose of being tracked at all times by the vehicle station. Of course, once this tracking operation is performed, variations in the strength of this same signal, used now as a carrier, can be detected and may serve to transmit information.

The problem of tracking the enormous Doppler shift of a continuous-wave signal by means of an extremely narrowbanded receiver constitutes the most exacting and the most crucial technical task encountered when endeavoring to maintain communication links over a line-of-sight range of 300,000,000 km. At the same time, the solution of this problem offers a rich reward, for it permits us to accomplish almost immediately another important task; namely, keeping track of the exact line-of-sight distance between the earth and vehicle stations. We shall see that the accomplishment of this second task will enable us to determine interplanetary distances, now known to only one part in a thousand, with an accuracy of one part in a billion; that is, with a millionfold greater accuracy.

Fortunately, the communications engineer knows how to track a continuous-wave signal over a frequency range enormously greater than his receiving bandwidth, as long as a certain condition is met, about which more will be said later. In principle, he solves this problem by generating a local continuous-wave signal of controlled frequency very nearly equal to the frequency of the incoming signal. He then "heterodynes"; that is, *beats* the incoming signal against the local signal, and utilizes their slow beat to make a phase motor rotate in exact step with that beat. The direction of its rotation is determined by whether the local signal has a higher or lower frequency than the incoming signal. This phase motor is geared in turn to the tuner of the local signal generator, and so controls its frequency as to make it always tend toward the frequency of the incoming signal.

The diagram below illustrates the sequence of apparatus which will perform the frequency-tracking operation just described. Most of this apparatus forms a so-called feedback or servoloop—the kind of apparatus organization about which much was learned during and since WW II, and which resembles the organization of the human body.

It is not essential to have a real phase motor and a mechanical gear box to perform the frequency-tracking task. Indeed, there are electronic equivalents of the phase motor and the gear box weighing one-hundredth the weight and consuming one-hundredth the power. These electronic equivalents are far better suited for a vehicle station when weight and power in orbit are at a real premium. The important thing is that this task can be accomplished provided—and here is the certain condition alluded to above—that the *rate of change* of the Doppler shift is not too high.

Doppler Shift Rate

The rate of change of the Doppler shift is exactly equal to the acceleration of the vehicle divided by the signal wavelength. When the vehicle is being launched this drift rate is limited by the available motor thrust, but once the vehicle is in its own solar orbit the relative acceleration of the earth and vehicle is very small.

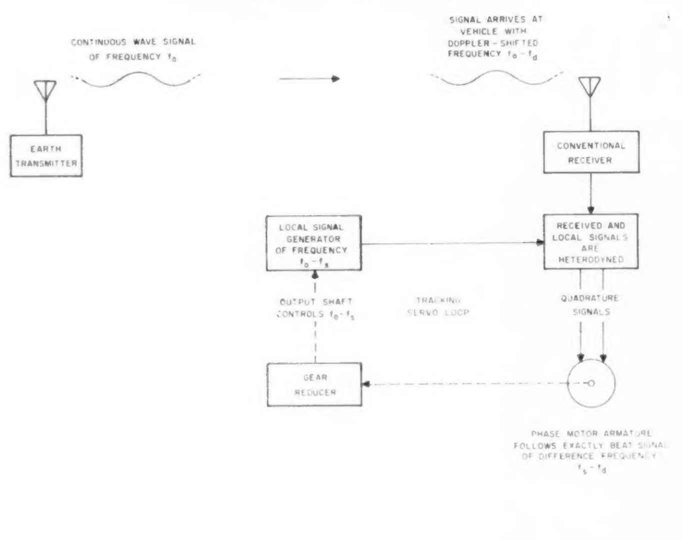
As an example, consider a vehicle launched with just a little more than earth-escape velocity, so that its orbit has a period of 380 days. The beat period between the earth and the artificial planetoid is 9253 days, so that after some 12 years the planetoid is nearly in opposition with respect to the sun. Its acceleration relative to the earth is then only 0.001 cm per sec^2, or one-millionth of g.

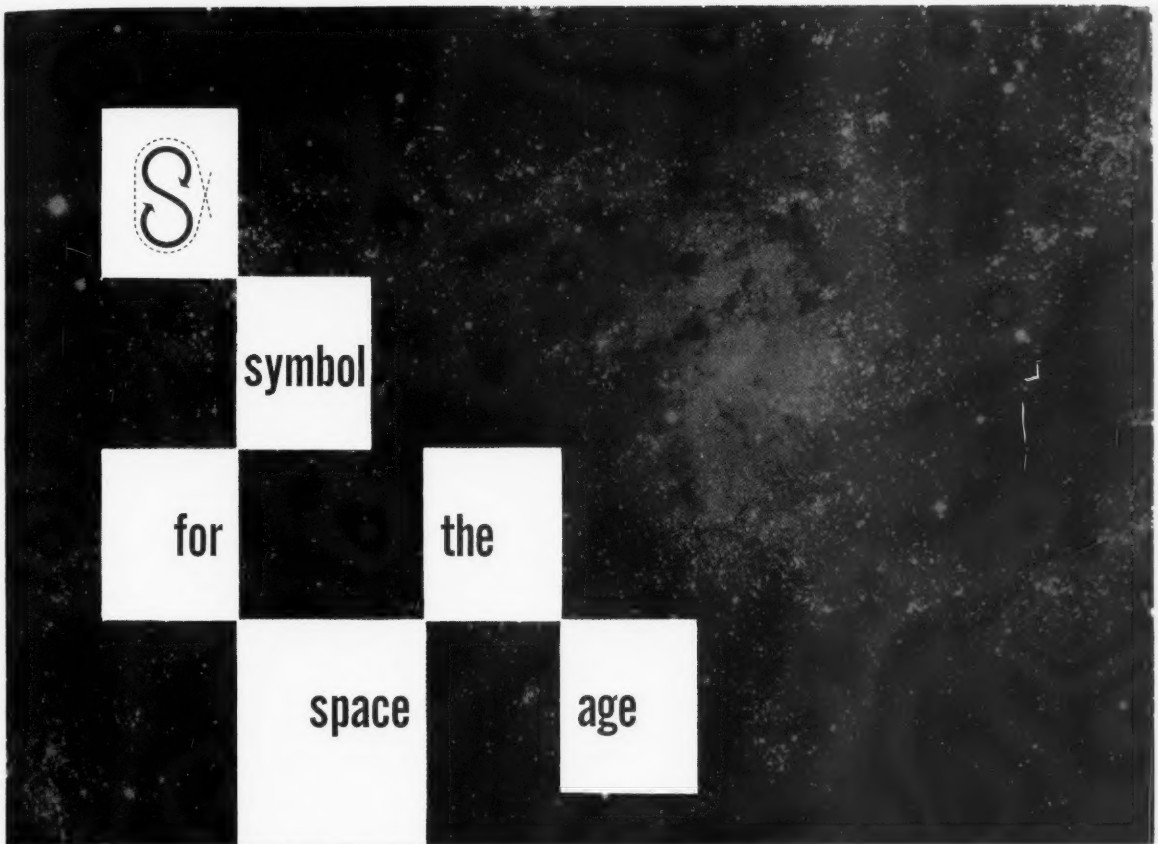
Dividing now this acceleration by the signal wavelength (10 cm), we obtain a Doppler drift rate of 0.0001 cps^2, which the system must be able to track. This drift rate is the square of the frequency—0.01 cps. This frequency has a special importance in our considerations, for the mathematical analysis of the situation described here shows that it is precisely the *narrowest possible receiving bandwidth* of a tracking system capable of following the relative earth-vehicle acceleration of one-millionth g when the transmitted wavelength is 10 cm.

These figures bring into relief the enormous importance of a well-designed frequency-tracking system. They show the possibility of narrowing the receiving bandwidth from the 100,000 cps required without frequency tracking to 1 ten-millionth of this value. In terms of emitted power, this means that watts will suffice, instead of ten's of megawatts, which are out of the question even for an earth station, not to speak of a planetoidal station.

We have seen that slow amplitude

One-Way Communication System




symbol
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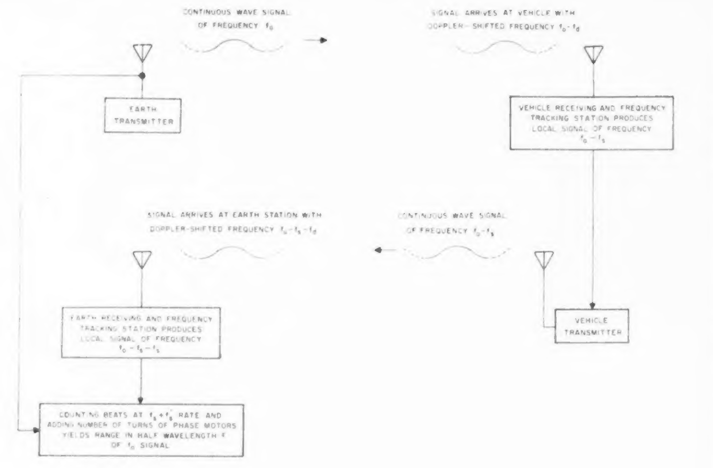
Two-Way Communication System as a Radio Interferometer



modulations of the transmitted carrier may serve to transmit information to the vehicle station. Now let us examine the fascinating results which can be accomplished by placing two such frequency-tracking systems end to end, so that signals may now be received back on earth from the vehicle station.

Let us note first, that with the frequency-tracking system diagramed on page 48 not a single cycle of the received signal is ever lost. The frequency of the local signal may differ ever so slightly from that of the received signal; but this very small difference frequency, at most equal to the receiving bandwidth (0.01 cps), controls the rotation of the phase motor of the servoloop, so that the number of cycles not exactly accounted for by the local signal are exactly "remembered" by the gear box.

Assume now that the vehicle station can reemit a strong continuous-wave signal, of the order of watts, having exactly the frequency of the local generator. It must be stated immediately that the reemission of a signal 1,000,000,000,000,000,000 stronger than a received signal of nearly the same frequency would block the receiver hopelessly.

But here again, the communications engineer has a bagful of tricks. Thus, he may mix the desired signal with other locally generated signals, and transmit this composite signal as well as these other local signals, so that the assemblage is only remotely harmonically related to the essential signal. The distant earth-station will then unravel these several signals and reproduce the desired signal. Alternately, he may retransmit a single continuous-wave signal, which is, for instance, exactly seven-sixth's the desired signal—for every six waves of the desired signal he retransmits exactly seven, and the inverse process is performed at the earth station, so as to retrieve the exact desired signal.

Whichever method is used, adequate filtering at the vehicle station will prevent the transmitted signals from masking the very weak desired signal. Yet, back at the earth station, a signal will eventually be obtained exactly as if the vehicle had retransmitted its locally generated signal. The assumption that this signal can be retransmitted is therefore a legitimate one, for it permits us to visualize what is essential in the operation of the entire system.

Consider now the operation of the entire system, which is illustrated diagramatically above. A continuous-wave signal generated at the earth station is received and tracked by the vehicle station which produces a locally generated signal. During any one interval of time, this local signal produces fewer cycles than are transmitted by the earth station, the difference being exactly equal to the number of wavelengths of the transmitted signal which the vehicle has traveled plus the number of rotations made by the phase motor during that interval.

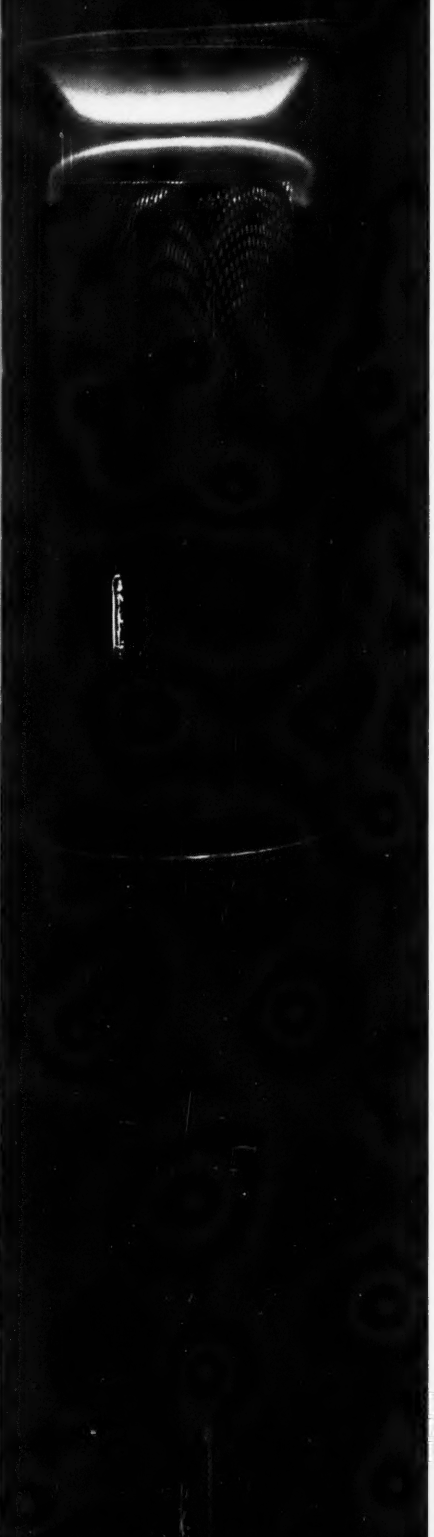
So far, not much use can be made of these facts, because the vehicle station does not know exactly the frequency of the transmitted signals. But the vehicle station retransmits its local signal, which is received and tracked at the earth station after having suffered a further Doppler shift on its return trip. There will be produced at the ground station a locally generated tracking signal which, during any one interval of time, will produce fewer cycles than were originally transmitted, the difference being now twice the number of wavelengths which the vehicle has traveled, plus the total number of rotations made by both phase motors during that interval of time.

Now good use can be made of these facts, for the original emitter is close at hand, and the count of the cycle difference between the original signal and the local earth-station tracking signal, plus the easily ascertainable number of phase motor turns, yields exactly twice the distance from the earth station which has been traveled by the vehicle station during that time interval. We thus reach the exciting conclusion that *here is a system which measures range with a precision of a fraction of a wavelength regardless of the range magnitude*, be it a few meters or several hundred million kilometers!

Why the Name

It is this circumstance which justifies the name "Radio Interferometry" selected for the title of this discussion, for the technique described here shares with the classical two-beam interferometer of Michelson the property of measuring with a precision of a fraction of one wavelength distances several orders of magnitude greater. Indeed, the availability of radiation much more monochromatic than, say, the green light of Mercury permits the radio interferometer to operate over ranges thirteen or more orders of magnitude greater than the wavelength utilized, whereas the optical interferometer is limited in practice to path differences only six orders of magnitude greater than the optical wavelength utilized.

The metrological implications of radio interferometry are also immediately apparent. Interplanetary parameters, in particular the sun's parallax, are known today with an absolute accuracy of only 1 part in 1000. On the other hand, assuming Newton's law of gravitation, with its Einstein corrections, to be exact over the distances involved in the solar system, interplanetary parameters are known relative to each other with an accuracy of one part in one billion. Radio interfer-



Stabilized two-stage flame, no additives

One of a series

The burning question of cool flames

Between the brief stage of not burning and burning, many hydrocarbons react with oxygen at temperatures well below that of normal flame combustion. But the reactions are usually transient and hard to analyze. At the General Motors Research Laboratories, we have been able to investigate the *effect of chemical additives on cool preflames.*

To do this, the almost invisible cool flames are stabilized for hours in a flat-flame burner, permitting careful examination of the retardation or acceleration effects of the additives. From more than twenty additives studied, experimental results indicate that some chemicals affect combustion through the mechanism of preflame reactions. We are now accumulating new information on these additives' mode of operation. For instance: emission spectra support the conclusion that tetraethyl lead reacts with the oxygenated compounds formed in cool flames to yield lead oxide vapor. These findings of when and how lead oxide is formed are important in resolving a current controversy of science — the combustion behavior of tetraethyl lead.

Studies such as this may lead to more economical and effective means of controlling unrestrained combustion — such as "knock" in reciprocating engines. The work is typical of GM Research's effort to provide useful information for a moving America. And in this way continue to keep our promise of "More and better things for more people."

General Motors Research Laboratories
Warren, Michigan

Iron carbonyl, an antiknock

Ethyl nitrate, a proknock

Iron carbonyl retards, ethyl nitrate accelerates central portion of cool flames.

ometry offers us, therefore, the neat possibility of expressing these parameters in terms of the wavelength of earthborne radiation with that same accuracy.

Indeed, two curious circumstances are brought into relief by these considerations. Since the most accurate measurements of length must be made by an interferometric method over vacuum distances of the order of at least one-billion wavelengths of the radio radiation utilized, we conclude that:

1. These most accurate measurements of length must perforce be conducted on an interplanetary scale.
2. The standard of length used—namely, the wavelength corresponding to some atomic clock period—cannot be reduced to other standards with an accuracy as high as interplanetary measurements made in terms of it.

The implication of this second point is striking: In the highly accurate metrology of the future, the question of the value of the velocity of light in terms of old standards, such as the meter and the sidereal second, will drop out of consideration. The standards of time and length will be, respectively, the wavelength and the period of the atomic clock radiation, and their ratio will be called c by definition, but will not be reducible to other standards with the same accuracy with which measurements will be made directly in terms of these standards.

High Accuracy

A remark should be made about the high accuracy which appears realizable from measurements made with extremely weak received powers. When this at first surprising circumstance is examined from the viewpoint of information theory, we realize that a very efficient use is made of these weak powers, for they deliver information about the range increments only—the burden of remembering the past range being placed on the observer and his instrumentation. Thus, these weak received powers deliver over an appreciable period of time the precious bits of information which, eventually, give the correction from any anticipated solar orbit to the actual orbit.

The reader may well conclude from this discussion of radio interferometry that, while the launching of planetoids is within the grasp of the rocket engineer, the nearly millionfold increase in range implied by this possibility will present the communications engineer with a new and fascinating challenge. It was our purpose to indicate how the communications engineer will probably meet this challenge. ♦♦

ARS news

Attendance of 600 Marks Solid Rocket Research Symposium

Richard D. Geckler, featured speaker at the banquet, makes a point with a smile.

PRINCETON, N.J.—An attendance of more than 600, compared with advance estimates of from 250 to 300, highlighted the ARS Solid Propellant Rocket Research Symposium held at Princeton Univ. here January 28–29.

The program organized by the Symposium Committee—headed by J. Preston Layton of Princeton as general chairman, with Ivan Tuhy of Rocketdyne, chairman of the ARS Solid Rocket Committee, and Martin Summerfield of Princeton in charge of technical papers, and John Langfeldt of Princeton handling arrangements—succeeded in its avowed purpose of bringing together solid rocket specialists from all over the country to discuss critical research problems in an effort to define the unknown areas in the light of what is already known today. All sessions were unclassified.

The meeting got underway Thursday morning, January 28, with a session on exhaust nozzle design and thrust control, and a panel discussion on combustion of metals, chaired by H. M. Sherey Jr. of Rohm and Haas. The panel, bringing together Irvin Glassman of Princeton, Derck Gordon of Stanford Research Institute, W. M. Fassell Jr. of Aeronutronic, C. P. Talley of Experiment Inc., and W. A. Wood of Rohm and Haas.

Guest speaker at the Thursday luncheon, at which Jerry Grey of Princeton, president of the ARS Princeton Section, host for the Conference, acted as toastmaster, was John Turkevich, Higgins Professor of Chemistry at Princeton, pinch-hitting for C. D. Perkins, who had unexpectedly been called to Washington. Dr. Turkevich's "Impressions of Soviet Science," based on a tour of duty last summer as lecturer on science at the U.S. exhibit in Moscow, was a fascinating exploration of the attitude toward science displayed by the many

(CONTINUED ON PAGE 58)

Seated at head table at the banquet at the Solid Propellant Rocket Research Symposium held in Princeton's Nassau Inn are (left to right) J. P. Layton, Princeton Univ., general chairman of the meeting; J. C. Elgin, Princeton Univ. dean of engineering; Dan Myers of Thiokol; Martin Summerfield, Princeton, a member of the Symposium Committee; banquet speaker Richard D. Geckler of Aerojet; Ivan Tuhy of Rocketdyne, chairman of the ARS Solid Rocket Committee and a member of the Symposium Committee; ARS President Howard S. Seifert; Jerry Grey, president of the ARS Princeton Section; Harry Smythe, chairman of the Princeton Univ. Research Board; and Robert Drake, chairman of the Princeton Mechanical Engineering Dept.

CREW STATION MOCK-UP—static evaluation of display concepts.

COED CONSOLE—dynamic simulation of prototype man/machine interface.

COED/IBM 704 FACILITY—speed and flexibility for real-time simulation of man/machine systems.

COED . . . computer operated electronic display

The airborne data processing system for the EAGLE missile concept uses advanced digital data handling complemented by the intelligence of the human operator. Coordinated transfer of data between man and machine is implemented with human-factored electronic display and control devices.

Balanced man and computer functions are assured in the development of the EAGLE electronic system through analysis and experimentation with realistic operational missions using the COED (Computer Operated Electronic Display) simulator. This simulation involves real-time programs for a large-scale digital computer which are integrated with cathode-ray-tube alpha-numeric displays and operator controls.

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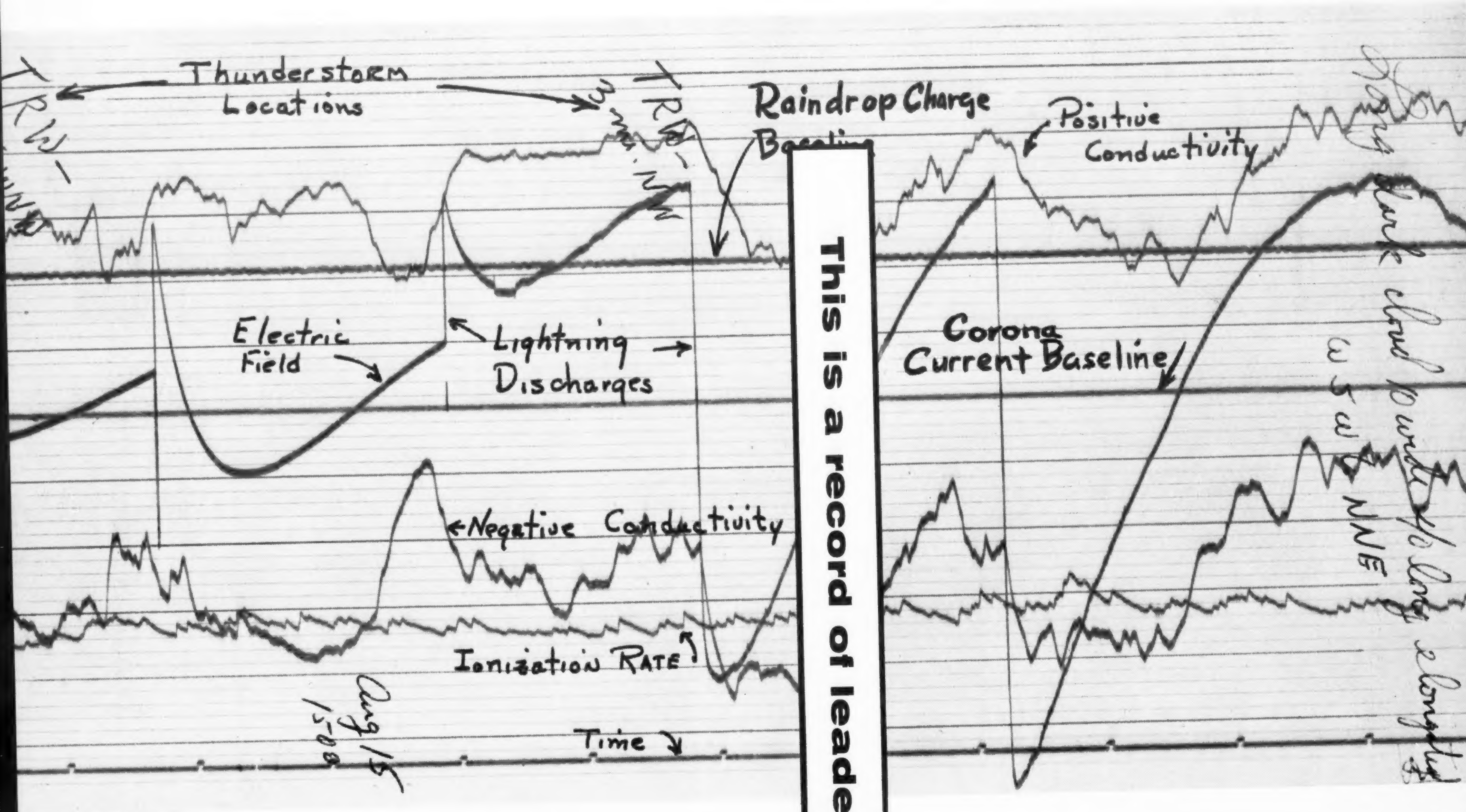


Honeywell 906A Visicorder record, actual size. Note longitudinal grid lines

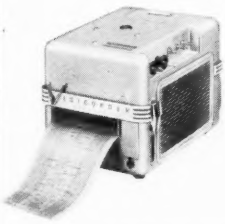
The U.S. Weather Bureau used a Honeywell Model 906B Visicorder Oscillograph to record directly this diary of a thunderstorm as it passed near the observation station on Mt. Washburn in Yellowstone National Park.

As the storm passed, the Visicorder measured and recorded 1) positive and negative electrical conductivity of the air, 2) the rate of ionization of air due to airborne radio-active particles and extra-terrestrial radiation, 3) the size and charge of individual raindrops, 4) the corona discharge current from an insulated tree and from a 4′x 6′ grass plot to determine current flow from the earth's surface to charge centers in the clouds, 5) times of camera exposure photographing cloud droplet size and electrical charge, 6) atmosphere potential gradient, and 7) time.

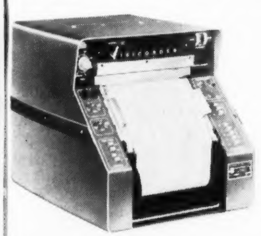
The Visicorder made this and many other records on Mt. Washburn without the use of power amplifiers. This feature, plus the extreme portability of the Visicorder, made it the ideal oscillograph for use in these studies.

Byron Phillips, U. S. Weather Bureau Scientist, monitors thunderstorm data as it is recorded by the Honeywell Model 906 Visicorder.

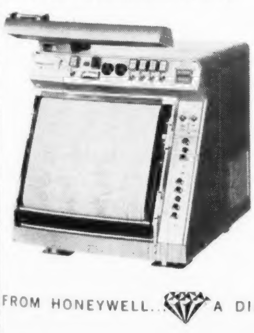
hip in weather research



Recent Models of the **906 Visicorder** incorporate time lines and grid lines and record up to 14 simultaneous channels of data.



The NEW Model **1108 Visicorder** with many automatic features and the convenience of push-button controls, is ideal for intermediate uses requiring up to 24 channels of data.



The Model **1012 Visicorder** is the most versatile and convenient oscillograph ever devised for recording as many as 36 channels of data.

The Honeywell Visicorder is the pioneer, completely proven, and unquestioned leader in the field of high-frequency, high-sensitivity, direct-recording ultra-violet oscillography. Here are some of the reasons why Visicorders provide the most accurate analog recordings available: constant flat response and sensitivity of galvanometers; grid-lines simultaneously recorded with traces to guarantee exact reference regardless of possible paper shift or shrinkage; flash-tube timing system for greater accuracy of time lines; superior optics for maximum linearity of traces.

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On the calendar

1960	
March 3, 10, 31	Gas Dynamics Colloquium on Combustion Instability in Solid Propellant Rocket Motors, High Altitude Aerodynamics in Relation to Experimentation, and Electrical Propulsion Systems, respectively, Northwestern Univ., Evanston, Ill.
March 6–9	ASME Gas Turbine Power and Hydraulic Conference, Rice Hotel, Houston, Tex.
March 9–10	Symposium on Processing Materials for Re-Entry Structures sponsored by Midwest Chapter of The Society of Aircraft Material and Process Engineers, Miami Hotel, Dayton, Ohio.
March 9–11	Conference on Mechanical Properties of Engineering Ceramics, North Carolina State College, sponsored by Office of Ordnance Research and NCSC.
March 9–11	ISA Temperature Measurement Symposium, Deshler Hilton Hotel, Columbus, Ohio.
March 23–25	**ARS Ground Support Equipment Conference, Statler-Hilton Hotel, Detroit.**
March 24–25	Symposium on Optical Spectrometric Measurements of High Temperatures, Univ. of Chicago.
March 24–26	National Conference on Aviation Education, Brown Palace Hotel, Denver, Colo.
March 29–31	ASME American Power Conference, Sherman Hotel, Chicago, Ill.
April 3–8	EJA Sixth Nuclear Congress, with ISA cooperating, New York, N.Y.
April 4–5	Solar Energy Symposium, Univ. of Florida, Gainesville, Fla.
April 4–8	AGARD Symposium on High Mack Number Airbreathing Engines, Milan, Italy.
April 4–8	ASME Nuclear Congress and Exhibit, Coliseum, N.Y.C.
April 4–8	American Meteorological Society Conference on Industrial Meteorology, Santa Barbara, Calif.
April 6–8	**ARS Structural Design of Space Vehicles Conference, Santa Barbara Biltmore, Santa Barbara, Calif.**
April 6–8	National Meeting of the Institute of Environmental Sciences, Biltmore Hotel, Los Angeles.
April 7, 14, 28	Gas Dynamics Colloquium on Rapid Magnetic Compression in a Deuterium Plasma, Gas Dynamics and Boiling Heat Transfer, and Flow of Ionized Gases, respectively, Northwestern Univ., Evanston, Ill.
April 11–14	ASM Weather Radar Conference San Francisco, Calif.
April 21–22	AIME Southwest Metals and Minerals Conference on Metals and Minerals for the Space Age, Ambassador Hotel, Los Angeles.
April 21–22	Annual Heat Transfer Conference, Oklahoma State Univ., Stillwater.
April 25–29	AGARD Boundary Layer Research Symposium, London.
April 25–29	ASME Metals Engineering Div.—AWS Conference, Hotel Biltmore, Los Angeles.
April 27–28	American Society for Metals Tri-Chapter Meeting on Materials—Key to Spaceflight, Sheraton Gibson Hotel, Cincinnati, Ohio.
April 27–30	American Meteorological Socety General Meeting with AGU, Washington, D.C.
May 2–5	ISA Sixth National Flight-Test Symposium, San Diego, Calif.
May 3–5	IRE-AIEE Western Joint Computer Conference, San Francisco.
May 9–11	ISA Third National Power Instrumentation Symposium, San Francisco.
May 9–12	**ARS Semi-Annual Meeting and Astronautical Exposition, Ambassador Hotel, Los Angeles.**
May 9–12	ISA Instrument-Automation Conference and Exhibit, San Francisco.
May 23–25	**ISA, ARS, IAS, AIEE National Telemetering Conference, Miramar Hotel, Santa Monica, Calif.**
May 24–28	Japanese Rocket Society 2nd International Symposium on Rocketry and Astronautics, University Club, Tokyo.
June 15–17	1960 Heat Transfer and Fluid Mechanics Institute, Stanford Univ., Stanford, Calif.
July 18–19	**ARS Propellants, Combustion, and Liquid Rockets Conference, Ohio State Univ., Columbus.**
July 21–27	3rd International Conference on Medical Electronics, sponsored by Institution of Electrical Engineers and International Federation for Medical Electronics, Olympia, London.
Aug. 15–20	**11th International Astronautical Congress, Stockholm, Sweden.**
Aug. 31–Sept. 7	10th International Congress of Applied Mechanics, Congress Bldg., Stresa, Italy.
Sept. 27–30	**ARS Power Systems Conference, Miramar Hotel, Santa Monica, Calif.**
Oct. 20–21	Hypervelocity Projection Techniques Conference, Univ. of Denver, Colorado.
Dec. 5–8	**ARS Annual Meeting and Astronautical Exposition, Shoreham Hotel, Washington, D.C.**

Soviet citizens who visited the exhibit.

Dr. Turkevich stressed the point that U.S.-U.S.S.R. contacts in science may lead to better understanding, and related one anecdote which helped sum up the problem. He recalled asking a young man, "Do you expect to go to the moon?" "Sure," was the reply. "And when are you going to come to New York?" "Well, I don't think I'm going to make it."

Afternoon sessions the same day centered on theoretical discussions of combustion instability and on combustion and ignition studies.

The banquet the same evening at the Nassau Inn was preceded by a reception sponsored by Thiokol Chemical Corp. and Princeton. Ivan Tuhy was toastmaster at the banquet, with Richard D. Geckler, vice-president, solid rocket plant, Aerojet-General Corp., the featured speaker.

In his address, entitled "Universities and Industry—Partners in Research," he urged that universities confine themselves to basic research and leave applied research to industry, adding that, if industry "gets an uncontrollable impulse to do basic research, let it give financial support to the universities, rather than get confused about its own mission," which, he felt, was to increase consumer goods.

Morning sessions the following morning took up the mechanical aspects of grain design and experimental work on combustion instability.

The Friday luncheon was chaired by Preston Layton, with the featured address given by J. T. Grey, director of research planning for Thiokol. Dr. Grey's topic was "Planned Research—A Prerequisite of Progress," and in his address he listed four parameters in planning research. These are that the research shall provide corporate growth, income, scientific knowledge, and satisfaction.

The meeting wound up with three informal round table discussions. The first, on combustion processes, was chaired by Dr. Summerfield; the second, on fluid-flow aspects of exhaust nozzles, by Dr. Grey; and the third, on mechanical properties of propellants and grain design, by E. H. Seymour of Reaction Motors.

A field trip to the Forrestal Research Center proved very interesting to those in attendance.

In addition to bringing out representatives of industry, government and military installations with an interest in solid rocket research, the meeting also drew representatives of 10 foreign countries, including the U.K., France, West Germany, Italy, Belgium, Switzerland, Israel, and the U.S.S.R.

The Symposium dealt with six particular areas of research: The com-

bustion of metals, the burning mechanism of solid propellants under steady-state conditions, oscillatory and unstable combustion of solid rocket engines, solid propellant ignitability, advanced concepts of exhaust nozzle design, and the mechanical design of large solid grains from the standpoint of the properties of a visco-elastic solid.

The Metals Session brought forth, among other things, some very interesting observations by Fassell of Aeronutronic of the manner in which particles of aluminum and magnesium alloy burn and the nature of the oxidation products, all based on simple experiments with metal powder in the several micron-size range injected into a gaseous fuel flame. Particles were trapped on cool collecting plates at various stages of oxidation, and it was seen in photomicrographs that the oxide formed a sturdy spherical shell of a certain size within which the metal melted and through which it diffused away. How to explain the size of the hollow shell, and how to introduce this into a theory of burning, was the subject of a vigorous floor debate, led mainly by Glassman of Princeton. Wood of Rohm and Haas showed some beautiful high-speed movies of the burning of metallized propellant at 500 psi, showing how close or how far from the surface the particles started to burn. Aluminum over 80 microns did not ignite in the reaction zone, but particles less than 40 microns ignited reliably close to the surface.

At the Combustion Processes Session, and later at the Round Table, opposing theories for the burning rate of composite solid propellants were discussed. The granular diffusion flame theory of Summerfield of Princeton, originally presented at the 1958 ARS Annual Meeting, was opposed by Nachbar of Lockheed who offered a two-dimensional columnar diffusion flame model, by Spalding of London who offered a multistage reaction zone model, and by partisans of Friedman's hypothesis that the monopropellant perchlorate flame determines the propellant burning rate. However, the Summerfield theory remains the only one at present that fits the observed pressure dependence of standard propellants. A discussion of the mechanism of erosive burning was introduced by Vanderkerckhove of Brussels.

The theoreticians had a stimulating session on the mechanisms of instability and the mode of action of metal powder as a suppressant. By a very convincing analysis, McClure of APL showed that the solid grain itself participates in the transverse oscillatory modes, as well as the gas in the hollow cavity, and pointed out that a reactive flame zone is able to amplify the oscillations under a broad range of conditions. Cheng of Princeton, relying on the concept of a time lag in the flame zone between a pressure variation and the resultant burning rate variation, showed that combustible metal powders suppressed instability by providing an oscillatory heat release mechanism out of phase with the surface burning oscillation. McClure argued against the time lag concept, and was supported by Shinnar of Israel, whose paper was a theoretical demonstration that the flame zone could amplify an oscillation, in the special case of strong erosive burning, without calling upon the concept of a time lag in burning rate. The audience enjoyed the controversy.

In a following session, the development people and the experimentalists helped to organize the known facts about instability. Outstanding papers were presented by Angelus of ABL and Price of NOTS. One of the most puzzling facts reported by Brownlee and Marble of CalTech was that the occurrence of instability seemed to depend on the "history" of the firing period up to that instant. For example, if a particular grain design showed instability after a measured time interval from ignition, the same grain should develop instability at an earlier time if some of it were first machined away to correspond to what had burned away. It did not. McClure offered a hypothesis in his theoretical paper that could account for this, but it was not proved.

In the ignition part of the Symposium, the papers were by the Summerfield group of Princeton and the Ryan group of the Univ. of Utah. They differed sharply on the mechanism of ignition of composite propellants: Ryan relied on the theory of Hicks which is based on a runaway exothermic reaction in the solid phase, whereas Summerfield presented a new theory that described ignition as first a gasification of the propellant components and then a runaway reaction in the gas phase. The Summerfield theory gave a quantitative result for the ignition time that agreed with

shock tube experiments. Ryan's data could be correlated by the Hicks theory, but with an ad hoc Arrhenius function. Further critical experiments seem to be necessary. Fishman of Stanford Research contributed informally some results of his work on ignition by radiant energy which supported the gas phase ignition theory, but others argued that solid-phase ignition is possible in nitrocellulose propellants, if not in perchlorate composites.

In the Nozzle Design and Thrust Control Session, the discussion was led off by a paper by Adelman and Keathley of United Research, who discussed reliability, accuracy requirements, and control requirements for solid engines of the ballistic type. Others discussed contour nozzles versus conical nozzles, comparing test results with theory. Great interest was aroused by a paper on plug nozzles by Berman and Crimp of GE. Not only is this type of nozzle a fascinating fluid-mechanical device, but it seems to offer certain advantages in performance and compactness over the conventional Laval nozzle. However, it is certainly more complex to construct and presents a cooling problem, but whether such barriers are important remains to be seen. Undoubtedly, plug nozzles will appear on some liquid engines in the future, but it is not clear that they belong on solid engines.

Last, but not least, the Symposium included two sessions on mechanical aspects of grain design. Williams of CalTech, who is also the chairman of the SPIA Committee on Structural Integrity, delivered a comprehensive lecture in which he outlined methods of analysis of strain distribution in grains, and then analyzed the problem of developing a criterion for failure. One of the great difficulties is to insert in the analysis a realistic yet tractable mathematical model for the viscoelastic behavior of the elastomeric propellant. It was on this point that a vigorous debate developed, in which Billheimer of Aerojet and Freudenthal of Columbia took part. A Rocketdyne group showed how these mechanical difficulties confronted the designer in the specific task of a two-million-pound thrust booster. Au of Hughes Aircraft also contributed to the discussion of strain distributions and criteria for failure, as did Vanderkerckhove of Brussels. Some beautiful photoelastic pictures in color were shown by Williams to show various stress distributions. This part of the Symposium turned out to be one of the liveliest of all.

Irwin Hersey and Martin Summerfield

1960 ARS Meeting Schedule

Date	Meeting	Location	Abstract Deadline
March 23–25	Ground Support Equipment Conference	Detroit, Mich.	Past
April 6–8	Structural Design of Space Vehicles	Santa Barbara, Calif.	Past
May 9–12	ARS Semi-Annual Meeting and Astronautical Exposition	Los Angeles, Calif.	Past
May 23–25	National Telemetering Conference	Santa Monica, Calif.	Past
July 18–19	Propellants, Combustion, and Liquid Rockets Conference	Ohio State Univ.	April 15
Aug. 15–20	11th International Astronautical Congress	Stockholm, Sweden	April 15
Sept. 27–30	Power Systems Conference	Santa Monica, Calif.	June 24
Dec. 5–8	ARS Annual Meeting and Astronautical Exposition	Washington, D.C.	Aug. 25

Send all abstracts to Meetings Manager, ARS, 500 Fifth Ave., New York 36, N.Y.

GSE Conference to Be Held in Detroit March 23-25

An expected audience of 1200 persons will gather in Detroit this month for the ARS Ground Support Equipment Conference, to be held at the Statler Hilton Hotel March 23–25 under the auspices of the ARS Test Facilities and Support Equipment, and Logistics and Operations Committees, and the ARS Detroit Section.

The program for the meeting, drawn up under the direction of B. J. Meldrum of Chrysler Corp's Missile Div., will schedule three classified and two unclassified technical sessions on the mornings of the three-day meeting, thus leaving the afternoons open for three classified and two unclassified field trips. There also will be a special evening session.

The conference will cover five main areas in these sessions: 1. A factual review of the types of problems encountered in actual field experience with currently deployed equipment; 2. a review of typical "second-generation" missile ground support equipment; 3. a look at some high spots in advances in mechanical and electrical ground support equipment; 4. an examination of what the Russian competition is doing; and 5. a summary of the unusual chemical, transportation, and legal risks involved in operation of the systems.

Field trips will include classified tours of the Michigan Ordnance Missile Plant, Detroit Arsenal, and Burroughs Corp.'s Military Electronic Computer Div., in addition to unclassified trips to the Ford Scientific Laboratory and the General Motors Technical Center.

Three luncheons and a banquet also are scheduled. I. M. Levitt, director of the Fels Planetarium in Philadelphia, will speak at the Wednesday luncheon on "The Moon—Target for Tomorrow." The Thursday luncheon will be addressed by C. Stark Draper, director of the Instrumentation Laboratory and chairman of the Aeronautics and Astronautics Dept. at MIT, who will speak on "The Balance Between Missile-Borne and Ground Support Equipment."

The Friday luncheon speaker will be Maj. Gen. Ben I. Funk, the new commander of the San Bernardino Air Material Area. His subject will be "The Impact of Ground Support Equipment and Its Effect on the Ballistic Missile Program." The banquet speaker for Wednesday evening has not been announced.

The Detroit Ordnance District is handling security arrangements for the meeting and has established a deadline of March 11 for the return of clearance forms. These forms are bound into the program, but additional copies are available from the ARS office in New York. Any clearance questions should be directed to Fain B. Patterson, Security Officer, Detroit Ordnance District, Detroit 11, Mich.

"You will note the opening session of the conference (9:30 a.m., Wednesday, March 23) is classified SECRET," Mr. Meldrum noted. "Admission will be controlled by proper authorization document and the bearer's identification (I.D. card or corporate "picture badge"—or equivalent).

"It is expected that over 1200 persons will attend the opening session. A moment's reflection will indicate the absolute impossibility of processing 1200 such documents early on the morning of Wednesday, March 23.

"Accordingly, the registration desk will be open on the afternoon and evening of Tuesday, March 22 from 3:00 to 10:00 p.m. **Please schedule your arrival in Detroit so that you can register Tuesday.** Failure to do this will probably make it impossible for you to attend the opening session."

The program follows:

Tuesday, March 22

MIXER

6:30–7:30 p.m. **Wayne Room**

Under the auspices of: Beaver Precision Products, Inc., Burroughs Corp., Chrysler Corp., Continental Aviation and Engineering Corp., Dearborn Machinery Movers Co., Inc., Electro Mechanical Products Co., Ford Motor Co., General Motors Corp., Kelsey-Hayes Co., Koebel Diamond Tool Co., Vickers, Inc., Wyandotte Chemical Corp.

Wednesday, March 23

WELCOMING MESSAGES

9:00 a.m. **Grand Ballroom**

B. J. Meldrum, Conference Program Chairman

G. Mennen Williams, Governor, State of Michigan

TECHNICAL INTRODUCTION TO THE CONFERENCE

9:00 a.m. **Grand Ballroom**

Howard S. Seifert, President, AMERICAN ROCKET SOCIETY

PROBLEMS AND TRENDS IN GROUND SUPPORT EQUIPMENT

(Secret)

9:30 a.m. **Grand Ballroom**

Chairman: Ray Eppert, Burroughs Corp., Detroit, Mich.
Vice-Chairman: Richard J. Egger, Burroughs Corp., Detroit, Mich.

- ✦Army—Roy A. Pugh, Army Rocket and Guided Missile Agency, Huntsville Ala.
- ✦Air Force—Maf. Benjamin N. Bellis, Air Force Ballastic Missile Div., Los Angeles, Calif.
- ✦Navy— Capt. Jock J. Hinman, Bureau of Naval Weapons, Washington, D.C.

LUNCHEON

12:00 Noon **Grand Ballroom**

Toastmaster: Leslie G. Taylor, General Manager, Aviation Divisions, Kelsey-Hayes Co., Detroit, Mich.
Speaker: I. M. Levitt, Director, Fels Planetarium, The Franklin Institute, Philadelphia, Pa.
Subject: "The Moon—Target for Tomorrow."

FIELD TRIPS

Buses will leave Statler Hilton Hotel from Bagley Street entrance for Tour 1, and from Washington Blvd. entrance for Tour 2.

2:00 p.m. **Tour 1**

Michigan Ordnance Missile Plant

(Confidential)

Director: Robert Wiltse, Chrysler Corp., Detroit, Mich.

The field trip will consist of a tour through the design, laboratories, and advanced design areas. The group will view the fabrication, test, and checkout of Redstone and Jupiter missiles side by side on similar production lines. Also, the group will see the fabrication of ground support equipment and its component parts for Redstone and Jupiter systems. The final area visited will be an outdoor display of a launch-site complex showing the placement of ground support equipment with a Jupiter missile in a simulated tactical launch area.

2:00 p.m. **Tour 2**

Ford Scientific Laboratory

Director: Colver Briggs, Ford Motor Co., Detroit, Mich.

Tour members will visit the Ford Rouge plant, the world's largest concentration of integrated factories, where raw ores are unloaded on the docks, smelted into iron, converted into steel, and transformed into engines, frames, bodies, and parts, and finally, completed automobiles. The Rouge plant employs 60,000 persons.

After a stop at the Ford Rotunda, "Show Place of the Auto Industry," tour members will be given a briefing on the company's vast research and engineering programs, then tour the new 720-acre research and engineering center and experience a turn around the Dearborn test track.

NASA GROUND SUPPORT EQUIPMENT FOR SPACE VEHICLES

8:00 p.m. **Grand Ballroom**

Chairman: Jerry Lynch, General Manager, Aeronutronic, a Division of Ford Motor Co., Newport Beach, Calif.
Vice-Chairman: Richard Morrison, Professor of Aeronautical Engineering, Univ. of Michigan, Ann Arbor, Mich.
Speaker: Homer J. Stewart, Director, Office of Program Planning & Evaluation, National Aeronautics and Space Administration, Washington, D.C.

Thursday, March 24

SECOND GENERATION OF GROUND SUPPORT EQUIPMENT SYSTEMS

(Secret)

9:00 a.m. **Grand Ballroom**

Chairman: Hans Hueter, Army Ballistic Missile Agency, Redstone Arsenal, Ala.
Vice-Chairman: Edward Hayes, Kelsey-Hayes Co., Detroit, Mich.

- ✦Minuteman Ground Support Equipment, Lt. Col. Francis K. Bagby, Air Force Ballistic Missile Div., Los Angeles, Calif.
- ✦Polaris Ground Support Equipment, Cmdr. Creighton W. Cook, Bureau of Naval Weapons, Washington, D.C.
- ✦Pershing Ground Support Equipment, Maj. Spencer Baen, Dept. of the Army, Office of Chief Research & Development, Washington, D.C.

ADVANCES IN MECHANICAL GROUND SUPPORT EQUIPMENT

9:00 a.m. **Wayne Room**

Chairman: Harold Lipchik, American Machine & Foundry Co., Santa Barbara, Calif.
Vice-Chairman: Ed A. Nielsen, Chrysler Corp., Missile Div., Detroit, Mich.

- ✦Handling of Large Rocket Engines, Stanley R. Parker, Rocketdyne, North American Aviation Inc., Canoga Park, Calif. (1069-60)
- ✦Transportation and Handling of the Saturn Booster, Julian S. Hamilton, Army Ballistic Missile Agency, Redstone Arsenal, Ala. (1070-60)
- ✦Use of Standard Military Vehicles for Missile Ground Support Equipment, Peter L. James, Chrysler Corp., Missile Div., Detroit, Mich. (1071-60)
- ✦Handling and Launching Considerations in Missile Design, Michael L. Mastracci, American Machine & Foundry Co., Greenwich, Conn. (1072-60)
- ✦Logistics, Supply, and Handling of Liquid Helium, John W. Marshall, Air Force Flight Test Center, Edwards AFB, Calif. (1073-60)
- ✦Handling, Transportation, and Storage of Liquid Hydrogen, C. Lincoln Jewett and Arthur A. Fowle, Arthur D. Little, Inc., Washington, D.C. (1074-60)

LUNCHEON

12:00 Noon **Grand Ballroom**

Toastmaster: Arch Colwell, Vice-President, Thompson Ramo Wooldridge, Inc., Cleveland, Ohio
Speaker: C. Stark Draper, Director, Instrumentation Laboratory and Chairman, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, Mass.
Subject: "The Balance Between Missile Borne and Ground Support Equipment"

FIELD TRIPS

Buses will leave Statler Hilton Hotel from Bagley Street entrance for Tour 3, and from Washington Blvd entrance for Tour 4.

2:00 p.m. **Tour 3**

Detroit Arsenal

(Confidential)

Director: Joseph B. Hayes, Ordnance Tank & Automotive Command, Detroit, Mich.

The field trip through Ordnance Tank & Automotive Command facilities at the Detroit Arsenal will include visit and observation of activities in the land locomotion research laboratories, the low temperature laboratories and model shops, and will feature specially prepared displays of ground support equipment under the cognizance of OTAC.

2:00 p.m. **Tour 4**

General Motors Technical Center

Director: Donald H. Loughridge, General Motors Corp., Detroit, Mich.

The tour will consist of observation of activities and facilities in the Research Laboratories.

RECEPTION

6:30 p.m. **Wayne Room**

BANQUET

8:00 p.m. **Grand Ballroom**

Speaker to be announced

Friday, March 25

ADVANCES IN ELECTRONIC GROUND SUPPORT EQUIPMENT

(Secret)

9:00 a.m. **Grand Ballroom**

Chairman: Malcolm P. Ferguson, Bendix Aviation Corp., Detroit, Mich.
Vice-Chairman: Russell O'Neal, Bendix Aviation Corp., Ann Arbor, Mich.

- ✦How Much Automaticity for Checkout Equipment? Sidney I. Firstman, The Rand Corp., Santa Monica, Calif.
- ✦Ballistic Missile Inertial Guidance Support Systems, Robert M. Mann, American Bosch Arma Corp., Garden City, N.Y.
- ✦Human Factors Requirements in Ground Support Equipment, Robert T. Eckenrode, Dunlap & Associates, Inc., Stamford, Conn.
- ✦Failure Prediction—A Method of Predetermining the Success or Failure of an Individual Missile, Allan T. Kneale Motorola, Inc., Phoenix, Ariz.
- ✦Advanced Automatic Checkout Equipment, James Q. Maloy, Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.
- ✦Requirements and Trends in Standardization, Col. Thurston T. Paul, Army Ballistic Missile Agency, Redstone Arsenal, Ala.

RUSSIAN GROUND SUPPORT EQUIPMENT

9:00 a.m. **Wayne Room**

Chairman: Clarence J. Reese, Continental Aviation & Engineering Corp., Detroit, Mich.
Vice-Chairman: John Squiers, Continental Aviation & Engineering Corp., Detroit, Mich.

- ✦Russian Trends in Ground Support Equipment, Author to be announced.

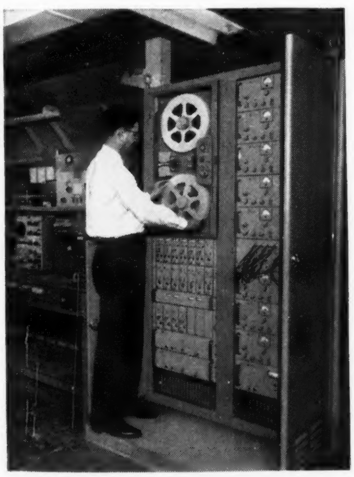
HAZARDS AND RISKS IN MISSILE SYSTEM HANDLING

(Panel)

10:00 a.m. **Wayne Room**

Chairman: Harold W. Ritchey, Thiokol Chemical Corp., Huntsville, Ala.
Vice-Chairman: John Squiers, Continental Aviation & Engineering Corp., Detroit, Mich.

- ✦Chemical Hazards in Handling Rocket Propellants, Alfred J. Zaehringer, American Rocket Co., Wyandotte, Mich.
- ✦Transportation Problems and Risks (Factory to Firing on Minuteman), George



(*Official U. S. Navy photographs*)

Drakely, Boeing Airplane Co., Seattle, Wash.

✦Legal Aspects of Missile Handling, G. Vernon Leopold, Special Committee on Space Law, State Bar Assn. of Michigan, Detroit, Mich.

LUNCHEON

12:00 Noon **Grand Ballroom**

Toastmaster: Harold R. Boyer, Vice-President, General Motors Corp., Defense Systems Division, Detroit, Mich.

Speaker: Major General Ben I. Funk, Commander, Hq., San Bernadino Air Material Area, Air Material Command, Norton AFB, Calif.

Subject: "The Impact of Ground Support Equipment and Its Effect on the Ballistic Missile Program"

FIELD TRIP

2:00 p.m. **Tour 5**

Burroughs Corp.
Military Electronic Computer Div.
(Confidential)

Director: Richard J. Egger, Burroughs Corp., Detroit, Mich.

The tour through Burroughs will include viewing of the modern assembly and testing equipment used in the division, including the areas used for AN/FST-2 radar data processing systems and the Atlas ballistic missile guidance computer. Visitors also will be shown the recently automated printed circuit production area. Attendance will be limited.

Conference on Structural Design of Space Vehicles Set for April 6-8 at Santa Barbara Hilton

Varying markedly from the established format of specialist conferences, the first meeting organized by the ARS Structures and Materials Committee will be held April 6–8 at the Santa Barbara Biltmore Hotel in Santa Barbara, Calif.

The meeting, which will gather an expected 500 to 600 specialists in this essential design field, will review, discuss, and analyze recent developments in materials, requirements, and synthesis. The three-day meeting, Structural Design of Space Vehicles Conference, will feature a total of five sessions and an informal dinner, with some 24 unclassified papers scheduled for presentation.

However, the customary morning-and-afternoon pattern of sessions will be replaced by a morning-and-evening session format to take advantage of the pleasant climate and to offset the lack of night-time activity in Santa Barbara.

"The conference setting, the informal dinner, the surroundings," George A. Hoffman of Rand Corp., program chairman for the conference, said, "were carefully chosen to attract a selected audience, one that could better enhance its knowledge and proficiency in structures and materials by a brief absence from the press of daily decision-making.

"The session topics cover some problems arising at first during boost, next when in orbit, and finally during reentry and landing. A session to emphasize the structures–materials aspects of space-frames is followed by the concluding report on planned and existing vehicles, with laboratories and government planning agencies presenting as wide a spectrum of unrestricted views as possible, thus stimulating interest in a variety of opinions and solutions to the coming problem of structures for spaceflight."

The complete program follows:

Wednesday, April 6

STRUCTURAL CRITIERIA AND DESIGN REQUIREMENTS DURING LAUNCH AND ATMOSPHERIC FLIGHT

9:00 a.m. **Loggia Room**

Chairman: George A. Hoffman, The Rand Corp., Santa Monica, Calif.

Vice-Chairman: Frederick L. Bagby, Battelle Memorial Institute, Columbus, Ohio.

✦Design Criteria for Space Vehicles to Resist Wind Induced Oscillations, A. A. Ezra and S. Birnbaum, The Martin Co., Denver, Colo. (1081-60)

✦The Application of Optimum Design Methods to the Thermostructural Optimization of High-Speed Missiles, Milton H. Schneider, Douglas Aircraft Co., Santa Monica, Calif. (1082-60)

✦Winged Booster Structures and Design, Kenneth E. Hogeland, Convair-Astronautics, San Diego, Calif. (1083-60)

✦Stability of Orthotropic Cylindrical Shells under Combined Loading, T. E. Hess, General Electric Co., Philadelphia, Pa. (1084-60)

✦Structure Weight and Configuration Estimating Data for Very Large Liquid Boosters, David K. McKinley, Aerojet-General Corp., Azusa, Calif. (1085-60)

DINNER

6:00 p.m. **Coral Casino**

Toastmaster: Howard S. Seifert, President, AMERICAN ROCKET SOCIETY.

Speaker: Milton U. Clauser, Director, Physical Research Laboratories, Space Technology Laboratories, Inc., Los Angeles, Calif.

STRUCTURAL AND MATERIAL DESIGN OF SPACE VEHICLES IN ORBIT

7:30 p.m. **Loggia Room**

Chairman: Raymond Bisplinghoff, Massachusetts Institute of Technology, Cambridge, Mass.

Vice-Chairman: Wolfgang H. Steurer, Convair, San Diego, Calif.

✦Design Considerations for Manned Space Stations, Kurt R. Stehling, National Aeronautics and Space Administration, Washington, D.C. (1086-60)

✦Liquid Hydrogen Transport Time Limits in Space, Charles C. Love Jr., Convair-Astronautics, San Diego, Calif. (1087-60)

✦Research on Automatic Erecting Structures Applicable to the Design of a Manned Space Station, Emanuel Schnitzer, National Aeronautics and Space Administration, Langley Field, Va. (1088-60)

✦Structural Limitations on the Impulsiveness of Astronautical Maneuvers, Murray Kornhauser, General Electric Co., Philadelphia, Pa. (1089-60)

Thursday, April 7

PROBLEMS OF RE-ENTRY AND LANDING ON SOLAR PLANETS

9:00 a.m. **Loggia Room**

Chairman: Max L. Williams, California Institute of Technology, Pasadena, Calif.

Vice-Chairman: Nathan Promisel, Navy Bureau of Weapons, Washington, D.C.

✦Vehicles for Exploration on Mars, Francis T. Cartaino, The Rand Corp., Santa Monica, Calif. (1090-60)

✦Materials for Re-entry, S. Ruby, Avco Research Laboratory, Wilmington, Mass. (1091-60)

✦Thermostructural Design of Entry Vehicles for Venus and Mars, Henry T. Ponsford, and Robert M. Wood, Douglas Aircraft Co., Santa Monica, Calif. (1092-60)

✦Application of Inflated, Expandable Structures to Orbital Flight and Re-entry, Frank B. Sandgren and James T. Harris, Goodyear Aircraft Corp., Akron, Ohio. (1093-60)

✦Particle Impacts on the Melt Layer of an Ablating Body, Edward W. Ungar, Battelle Memorial Institute, Columbus, Ohio. (1094-60)

SPECIAL STRUCTURAL AND MATERIALS PROBLEMS IN PRESSURE VESSELS AND OTHER COMPONENTS

7:00 p.m. **Loggia Room**

Chairman: Alan V. Levy, Hughes Tool Co., Culver City, Calif.

Vice-Chairman: Frederick L. Bagby, Batelle Memorial Institute, Columbus, Ohio.

✦Analytical Design Concepts Derived Specifically for Developing New or Existing Alloys for Cryogenic Use, K. R. Agricola, N. Ida, and F. R. Schwartzberg, The Martin Co., Denver, Colo. (1095-60)

✦Space Structure Design with Composite Materials, Hans U. Schuerch, Astro Research Corp., Santa Barbara, Calif. (1096-60)

✦Critiera for Meteorite Protection, Robert A. Gemmell, United Aircraft Corp., East Hartford, Conn. (1097-60)

✦Composite Materials, E. Scala, Avco Research Laboratory, Wilmington, Mass. (1098-60)

✦Design Criteria and Analyses for Thin-Walled Pressurized Vessels and Interstage Structures, Thomas J. Hart, Lockheed Aircraft Corp., Menlo Park, Calif. (1099-60)

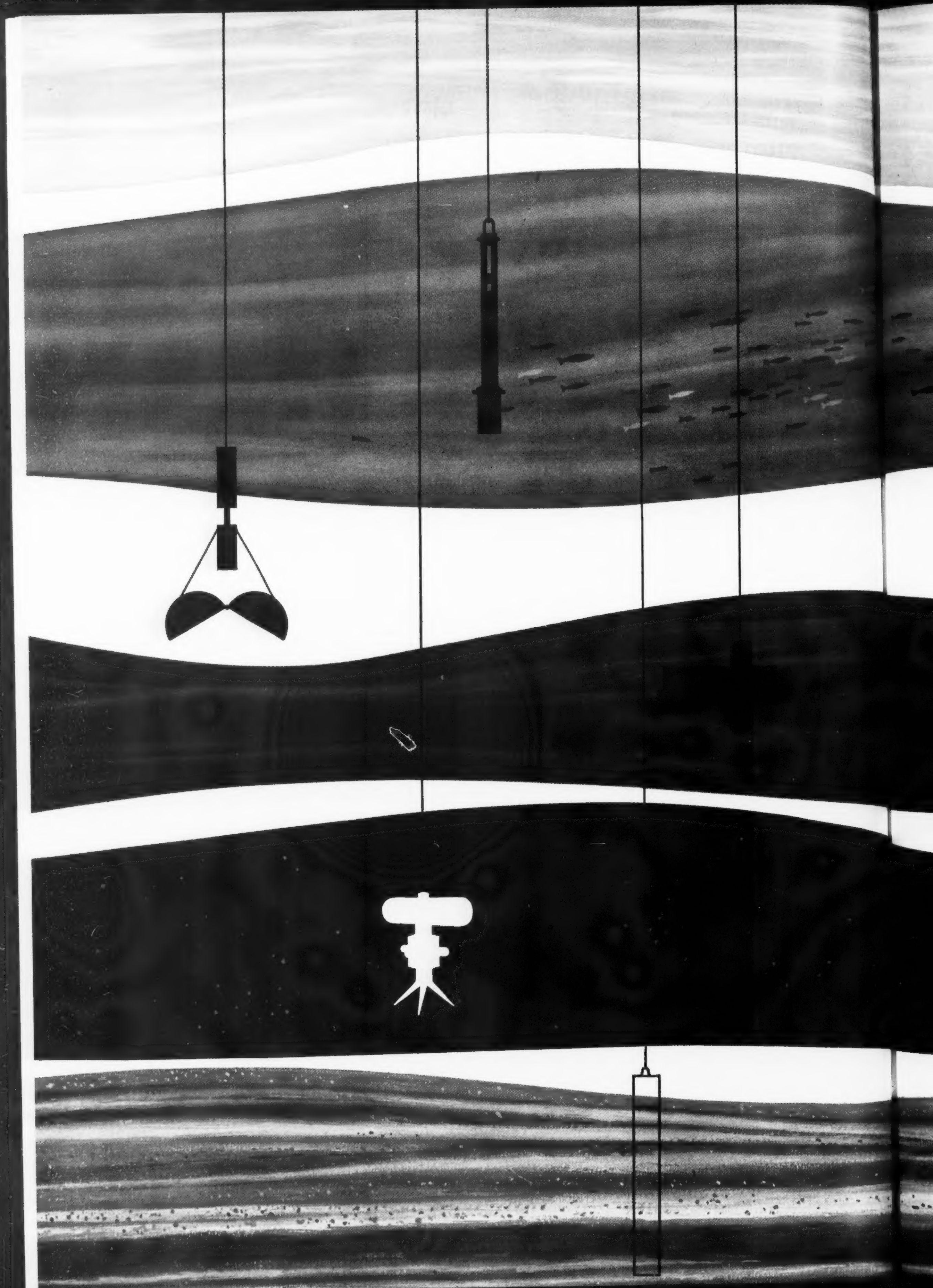
Friday, April 8

DESIGN REPORTS ON PLANNED OR EXISTING VEHICLES

9:00 a.m. **Loggia Room**

Chairman: George Gerard, New York University, New York, N.Y.

Vice-Chairman: Edward A. Simkovich, Republic Aviation Co., Farmingdale, N.Y.



✦Structural Design of the Tiros Meteorological Satellite, Robert W. Northup, Radio Corp. of America, Princeton, N.J. (1100-60)

✦Structural Design of a Manned Satellite Laboratory, J. W. Bilodeau and D. M. While, Chance Vought Aircraft, Inc., Dallas, Texas. (1101-60)

✦Design Considerations for the Explorer VI Payload Structurers, Phillip N. Anderson, Space Technology Laboratories, Los Angeles, Calif. (1102-60)

✦A Proposed Ground and Flight Program to Develop Space-Age Materials, Morris Steinberg, J. Fox, and Bruno Augenstein, Lockheed Aircraft Corp., Palo Alto, Calif. (1103-60)

✦Development of the Capsule Pressure Vessel for Project Mercury, Fred Sanders, McDonnell Aircraft Corp., St. Louis, Mo, (1104-60)

Maryland Space Education Institute Takes a Challenge

The challenge of education reveals a society's strength in depth. The need for more and continually improving public education in astronautics forms part of the educational challenge today.

The response to this need by the ARS Maryland Section and the Univ. of Michigan, working in cooperation, has been a Space Education Institute, which has already been through a successful term.

The two institutions renew their efforts this spring with a Space Education Institute running from February 29 to May 2. Being held at Symonds Hall, College Park, Md., the Institute will comprise nine sessions, as follows: Impact of the Space Age on Society—Charles W. Chillson; Rockets and Spaceflight—Milton W. Rosen; Space Propulsion Systems—William C. Cooley; Man's Functions in Space Travel—Milton A. Grodsky; Controls and Guidance for Rockets—Giles S. Strickroth; Educational Requirements for the Space Age—Joseph M. Rowland; The Rocket as a Research Vehicle—Warren W. Berning; Satellites and Interplanetary Travel—Peter A. Castruccio; and Science Teaching and the Space Age—Robert Carleton.

The stated objectives of this Institute seem worth repeating here:

1. To make available to educators and other interested adults information related to space science that is not readily available in published form.
2. To mitigate against misinformation and reduce educational lag.
3. To relate science teaching to contemporary trends.
4. To show the integration of mathematics, science, social studies, humanities, and fine arts in the Space Age.
5. To familiarize educators and other interested adults with the new terminology of the Space Age.

The fee for attending all nine sessions of the Institute is $14 per person. Requests for additional information and registration forms may be addressed to the Director of Institutes, Univ. of Maryland.

Liquid Rockets-Propellants Conference To Be Held at Ohio State Univ. July 18-19

An ARS Liquid Rockets and Propellants Conference will be held July 18-19 at the Ohio Union Building, Ohio State Univ., Columbus, Ohio. Prompted by the enthusiastic response to a similar meeting last summer, it will be jointly sponsored by the ARS Liquid Rocket and Propellants and Combustion Committees.

General Chairman for the conference is Loren E. Bollinger of the Department of Aeronautical Engineering at Ohio State. Program co-chairmen are Alexis W. Lemmon Jr., of Battelle Memorial Institute, Columbus, representing the Propellants and Combustion Committee, and Martin Goldsmith, Rand Corp., Santa Monica, Calif., representing the Liquid Rocket Committee.

Several unclassified technical sessions are being planned, and some session chairmen have already been appointed. In the propellants area, sessions and chairmen are: Storable propellants, Clair M. Beighley, Aerojet; monopropellants, Charles J. Marsel, NYU; and properties and thermodynamics, J. D. MacKenzie, GE Research Labs. Additional sessions in the area of liquid rockets and general sessions will be announced shortly.

Papers for presentation at the conference should be submitted to the session chairmen or program co-chairmen. Deadline for papers is April 15, although brief abstracts of planned papers would be welcomed in advance of that date.

IAF Abstract Deadline

ARS members wanting to submit papers for presentation at the 11th International Astronautical Congress, August 15-20, at The Royal Institute of Technology in Stockholm, Sweden, must send abstracts in English to reach the ARS Program Committee, 500 Fifth Avenue, N.Y. 36, N.Y., by April 15th.

Technical Committee Coordinator

Brooks T. Morris of Marquardt Corp., 1959 ARS National Program Committee Chairman, has been named Coordinator of Technical Committees for the coming year by ARS President Howard S. Seifert.

Another ARS Conference Added to Meeting Schedule

Another ARS special subject conference was approved by the Board of Directors at its meeting in New York on January 27. It will be a Power Systems Conference, to be organized by the Power Systems Committee and held at the Miramar Hotel in Santa Monica, Calif., Sept. 27-30.

Three More Companies Become ARS Corporate Members

Three more companies have become corporate members of the American Rocket Society. The companies, their areas of activity, and those named to represent them in Society activities are:

Bourns, Inc., Riverside, Calif., manufacturer of position, pressure, and acceleration transducers for control, ground support, and telemetering; leadscrew-actuated potentiometers; resistors; switches. Representing the company in ARS activities are A. J. Unetic, vice-president and Instrument Div. general manager; E. J. Geoppinger, director of sales; J. H. Pamperin, vice-president and Trimpot Div. general manager; D. P. Vaughan, director of sales; and D. F. Royce, assistant to the president.

Electro-Optical Systems, Inc., Pasadena, Calif., producer of ion and plasma propulsion systems; energy conversion and advanced power systems; space defense systems; and en-

gaged in advanced optical guidance and homing techniques and solid state physics. Named to represent the company in ARS activities are: Irving Weiman, senior physicist, Solid State Div.; Joseph Neustein, principal scientist, Energy Research Div.; Duane D. Erway, and Water R. Menetrey, staff engineers, Energy Research Div.; and John Teem, senior scientist, Fluid Physics Div.

Johns-Manville Sales Corp., New York, N.Y., manufacturer of insulating materials and reinforced plastics and molders of finished parts. Named to represent the company are D. L. Hinmon, vice-president and general manager, Industrial Insulations Div.; E. F. Briggs, sales manager, Aviation Products; S. A. Tompkins, manager, nuclear energy; L. M. Hedges, staff manager, Aviation Products; and J. A. Morgan, sales manager, Aviation Products-Pacific Coast.

A Space Trip to Japan

Last fall, Col. John P. Stapp, recent ARS president, Lt. Col. David G. Simons, and Col. K. E. Pletcher, all of the USAF, attended the meeting of the Japanese Rocket Society at Tokyo Univ. and gave papers on space medicine. Above, the participants at the space-medicine session, with Prof. Hideo Itokawa (far left), JRS Director and ARS member, and other JRS members.

SECTIONS

Central New York: Under the auspices of its Education Committee, the Section has begun a youth education lecture series. To inaugurate this series, **Donald U. Bessette**, of GE's Defense Systems Dept., gave an extensive talk to Boy Scout Troop 30, Syracuse, N.Y., on rocket fundamentals.

The Education Committee, while not quite four months in operation, has organized efforts to (1) sponsor, locally, a Boy Scout merit badge in rocketry, (2) procure funds for a one-year college scholarship, (3) present a series of lectures covering basics of guidance, propulsion, and structures to the high school science clubs in the metropolitan Syracuse area, (4) provide lecturers to interested civic organizations, and (5) participate in a Saturday morning TV program called "Ten O'Clock Scholar."

—**C. M. Clarke**

Chicago: The Section was host to a joint meeting with the IAS December 9, at which **John P. Hagen** of NASA presented an illustrated lecture on "What We Learned with Satellites During the IGY."

Dr. Hagen explained that prior to the IGY probing of the upper atmosphere was limited to about 150 miles with rockets. From these tests, it was learned that the ionosphere was not composed of distinct layers, as had been previously supposed, and that electron density increased up to a certain limit. Temperature measurements were also made in these tests.

From IGY data, it was possible to compare the atmospheric model postulated by rockets with quantities actually measured by satellites. Density was determined from drag measurements and by observing orbits. Temperature was then calculated from pressure and density measurements.

It was also possible to compare the radiation of cosmic rays with the Van Allen findings. Instead of two distinct belts, it now appears that there is but one, which follows the lines of force of the geomagnetic poles. High-speed electrons and protons come in from space and are reflected back and forth between the poles. Man in space

Chicago Sections Hear IGY Results

A recent joint meeting of Chicago ARS and IAS sections heard John P. Hagen of NASA discuss "What We Learned with Satellites During the IGY." Above, C. C. Miesse, president of the ARS Section, presides as the meeting gets underway, with Joe Islinger, IAS Section president, on his right.

Left to right, Ed Hammer, Ray Waugh, and Jess Brown of the Univ. of Michigan Chapter discuss its Project Trisos, a design study of a vehicle for intersolar-system cruising.

could travel through this belt rapidly, but could not stay in an orbit in it for extended lengths of time.

In conclusion, Dr. Hagen stated that work will continue at a higher level than that done during the IGY.

—R. G. Warder Jr.

Cleveland-Akron: The Section's January meeting, held jointly with the local ASME Section, went off quite successfully. Highlights of the evening included an interesting talk, a fine dinner, and a delightful cocktail hour.

Dave Mallon, of the Allison Div. of General Motors, discussed "The Stirling Cycle and Its Application for Space Power." His talk, including slides and a demonstration unit, emphasized the merits of this cycle relative to a mercury Rankine cycle for low-power space applications. This particular comparison was thoroughly enjoyed by the many Thompson Ramo Wooldridge personnel in the audience, who are the original proponents of the mercury Rankine cycle. A vigorous question-and-answer session followed the talk, with the issue far from settled in the end (as expected).

TRW sponsored the cocktail hour held at their Auto Museum. A display of advanced, high-performance TRW hardware and concepts, in the form of models, was also provided.

—Richard G. Gido

Kansas City: At the January dinner meeting, the following new Section officers were installed: Charles R. Burke, president; Paul L. Klevatt, vice-president; Stanley F. Mathews, treasurer; and Fred J. Bergman, secretary. Guest speaker for the evening was **Col. Russel E. Felix,** USA, who discussed "The Army Missile Program." Col. Felix, who is with the Department of Nuclear Weapons and Vehicles, used slides and a motion picture to highlight his discussion of Army missiles, warheads, and the tactical usage of various weapons. This was an especially gala affair because one year ago on this date Col. John P. Stapp, USAF, presented us with our charter.

—F. J. Bergman

Northern California: In December, the following officers were elected for terms in 1960: Bernard Ellis, president; C. Fred Hansen, vice-president; Howard M. Kindsvater, secretary; Norman Fishman, treasurer.

—C. Fred Hansen

Pacific Northwest: The December meeting, held in the Health Science Building of the Univ. of Washington, heard **George S. Sutherland,** of Boeing's Advanced Systems Research group, discuss recent advances in space propulsion.

Section officers elected at this meeting for terms in 1960 were D. M. Van Ornum, president; F. D. Reynolds, vice-president; R. W. Carkeek, secretary; and R. L. Farmer, treasurer.

—Richard W. Carkeek

Southern Ohio: Four successful meetings have characterized the activities of the Section recently.

At its most recent dinner meeting, December 15, the Section was host to **Walter A. Good,** physicist of Johns Hopkins Univ., and **A. A. Hafer,** of GE's Aircraft Nuclear Propulsion Dept. Dr. Good spoke on, "Twenty Years with Radio-Controlled Model Planes," and Mr. Hafer discussed, "Mission Considerations for Nuclear Propulsion." More than 60 people attended the dinner, which was jointly sponsored by the local ARS, AIEE, and IRE sections. Over 125 people were guests after dinner during the talks.

At the November meeting, **Elmer P. Warnken,** president of the Cincinnati Testing Laboratories, spoke to members of ARS and members of the Institute of Environmental Sciences on "High-Temperature Plastics in Missilery."

In October, **Ernst Steinhoff,** director of the missile department of Avco's Crosley Div., was guest speaker, discussing "The Role of Electronics in Space Research." Dr. Steinhoff has been in the U.S. since 1945. Before then he lived in Germany, where during WW II he was technical director of flight mechanics, ballistics, guidance, and control and electronics at Peenemunde.

Southwestern Michigan Section Chartered

John D. Moeller (left), president of the new Southwestern Michigan Section, receives ARS charter from Charles W. Williams, past president and one of the founders of the Detroit Chapter, at ceremonies in Kalamazoo, Mich., where the Section is headquartered.

In September, **Col. John P. Stapp,** then ARS president, spoke before a joint meeting of the local IRE and ARS section on "Manned Versus Unmanned Space Observations." Augmenting his talk were slides and movies showing what happens to human volunteers who ride high-speed rocket sleds, swings, catapults, and other decelerating devices. The motion picture demonstrated what the human body can stand when it is traveling at high speed and is stopped quickly. Over 100 people attended this meeting.

—Richard E. Stockwell

STUDENT CHAPTERS

Univ. of Colorado: The Chapter held its first meeting of 1960 on January 12. **Elliot Katz,** principal engineer for propulsion systems of Martin-Denver, spoke to the members on "Rocket Propulsion,"—fundamentals of rocket motors, present and future propellants, and advanced propulsion system. Following his talk, a 20-min color film on Titan testing was shown.

—John G. Shaffer

Univ. of Michigan: The fifth annual joint meeting of the Detroit Section and the Student Chapter was held December 4, preceded by a joint dinner. Guest speaker for the evening was **Col. M. E. Griffeth,** who is Special Projects Officer at Cape Canaveral. He spoke about the testing range itself, its facilities, and some of its operations. Also shown was a film of successes and failures of some of the missiles tested at the Cape.

Our Chapter is initiating a long-term project to design a space vehicle capable of cruising throughout the solar system gathering data on its bodies and phenomena. The vehicle will be called the *Solar System Scientific Observation Station,* or Project Trisos. Jess Brown is chairman of this project.

—Judith M. Forde

Univ. of Oklahoma: The November meeting was held in Felgar Hall on the Univ. of Oklahoma campus. Our guest speaker, Robert Graseley, of the U.S. Naval Ordnance Test Station, China Lake, Calif., gave an interesting talk on "Prospects of Rocketry," and showed a short movie displaying the various facilities of NOTS.

—John K. Totten

Cajun Motors Available

Thiokol's Elkton Div. has produced its 1000th Cajun rocket motor, and can now offer this engine to qualified industrial and scientific groups at prices beginning at $1286 each. ♦♦

Hydrogen for the Space Age

(CONTINUED FROM PAGE 27)

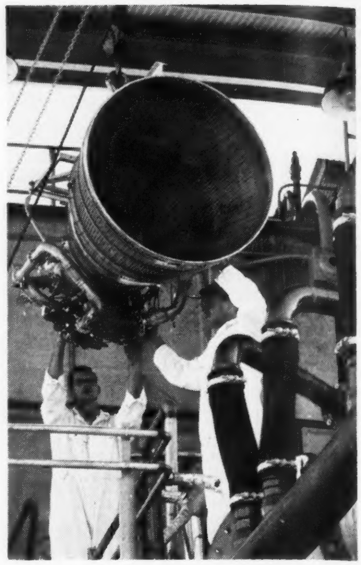
Here again, hydrogen comes to the fore with a specific impulse well over twice that of any other expellant. At probable reactor operating temperatures, the specific impulse of nuclear rockets using hydrogen can be expected to be double that of the best chemical systems. Hydrogen may give an additional bonus when considering space probes that require landing on and returning from a distant planet. Since a major portion of the takeoff gross weight is required to boost the fuel necessary for the return trip, much smaller vehicles could make the trip if they could be refueled. Since water may exist on some of the other planets, it may be speculated that hydrogen could be separated at the destination, using power from the rocket's nuclear reactor. This planetary "gas station" would lead to enormous savings in vehicle weight or corresponding increases in payload capability.

In view of the payload advantages obtainable with hydrogen, and considering its excellent combustibility, it is really remarkable that hydrogen was not used in the earliest rocket experiments (as it was in the earliest German turbojet). The late entry of hydrogen into practical rocketry probably can be ascribed to former concern over the availability and handling problems of liquid hydrogen. The USAF hydrogen plants testify that liquid hydrogen can be produced reasonably. Initial work by Pratt & Whitney Aircraft with liquid hydrogen was conducted in remote and widely separated test stands to minimize any possible hazards, since previous experience had been accumulated in laboratory-scale tests. As large-scale experience built up, handling techniques and improved cryogenic equipment have been developed so that experimental work can be conducted in more conventional surroundings. As an example, a typical test area, having over a dozen test stands, is used both for liquid oxygen and liquid hydrogen component development. Liquid hydrogen is supplied to this test complex through a 1500-ft-long pipeline.

Three Basic Systems

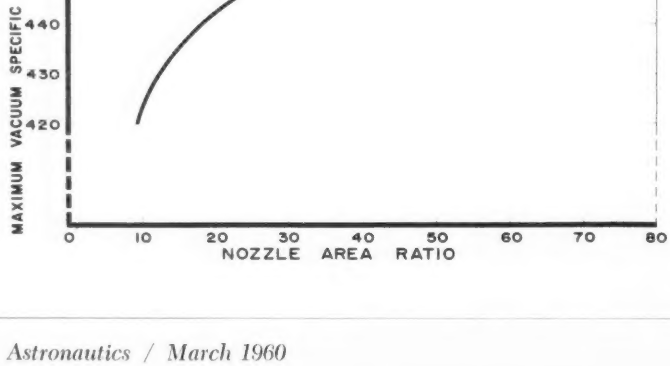
In considering the application of oxygen and hydrogen to upper-stage vehicles, there are three basic types of systems which merit discussion. These are (1) the use of low-pressure tankage with a regeneratively cooled, turbopump-fed engine, (2) the use of pressurized tankage supplying a regeneratively cooled thrust chamber, and (3) the combination of pressurized tankage with an uncooled (ablating) motor.

The pressurized tank systems dictate lower thrust-chamber pressures than for the turbopump system, in order to minimize vehicle tank and pressurizing system weight. These lower chamber pressures, in turn, result in a larger envelope for the engine and corresponding increases in engine weight. Combustion-chamber pressures on the order of 60 psia, with tank pressures of about 100 psia, appear to provide a minimum engine-plus-propellant supply system weight for these pressurized configurations. Pressurized systems with ablating thrust chambers will not have the payload capability afforded by regeneratively cooled chambers, owing to the substantial weight of ablating material that must be used for the firing durations of interest in most space missions. The table on page 77 compares the payload performance of the three types of oxygen-hydrogen rocket engines obtained with a hypothetical top stage of 20,000-lb gross weight designed to provide a velocity increment of 17,000 fps.



Shown being hoisted into the firing bay of a stand, the XLR-115 hydrogen-oxygen engine, which will provide the big kick for the upper stages of the Centaur rocket, has now been static-fired for as long as several minutes.

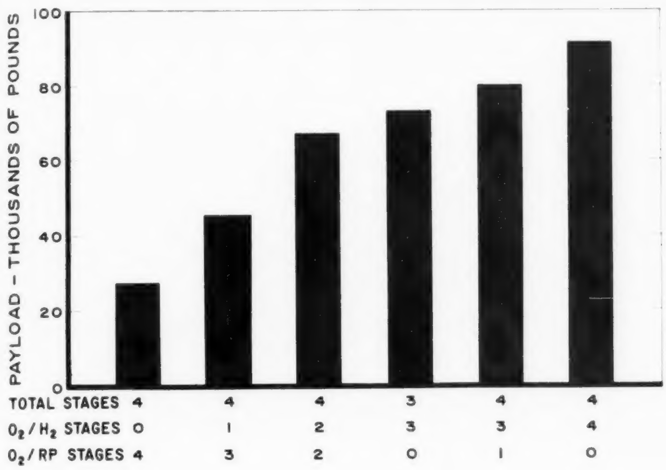
Oxygen-Hydrogen Rocket Theoretical Performance



Regenerative Cooling a Must

As can be seen from this table, a regeneratively cooled thrust chamber is necessary to obtain with hydrogen a significant degree of superiority over noncryogenic propellants. The remarkable heat capacity of hydrogen makes regenerative cooling a practical proposition. Of the two regeneratively cooled engines, the turbopump system provides a clearcut margin of payload superiority. Several years' experience in the development of liquid-hydrogen pumps has shown that a turbopump system can be developed without sacrificing reliability. It is of interest to note that the turbopump

24-Hr Equatorial Orbit Payload 6-Million-Lb-Thrust Booster



and regenerative-cooling experience gained with an oxygen-hydrogen engine is directly applicable to hydrogen-propellant nuclear rocket technology.

The use of oxygen-hydrogen engines in upper stages implies the need for high expansion ratios to realize the specific impulse obtainable with these propellants. The variation in peak specific impulse as a function of nozzle-area ratio indicates that, at extremely high area ratios, the penalty in engine weight will overbalance the gain in specific impulse. In the practical case, improvement in stage performance probably obtains up to area ratios of at least 40. However, vehicle limitations on the engine envelope size may require compromising the area ratio to less than that desired by theoretical considerations. Specific impulse is reasonably insensitive to mixture ratio variations on the order of ±15 per cent, and normal development should provide specific impulse values at least 90 per cent of ideal. Specific weights for turbopump engines in the range 0.010 to 0.015 pounds per pound thrust appear feasible, depending on the expansion ratio and engine size chosen. For most space missions, analysis has shown that a wide range of thrust-to-weight ratios can be tolerated for oxygen-hydrogen upper stages without seriously affecting payload capability. For this reason, two or possibly three sizes of oxygen-hydrogen engines should fulfill all space mission requirements, using existing and planned boost systems.

In the 15,000-lb-thrust class, development of an oxygen-hydrogen rocket engine was initiated for the Convair-Astronautics Centaur vehicle

Performance of Twenty-Thousand Pound Satellite Stage

Engine Type	Propellant Supply	Payload at 17,000 fps $\overline{\Delta}$V, lb
Regeneratively cooled, O_2-H_2	Turbopump	4000
Regeneratively cooled, O_2-H_2	Pressurized Tanks	3000
Ablating, O_2-H_2	Pressurized Tanks	2400
Regeneratively-cooled, storable propellants	Turbopump	1800

by ARPA and the Air Force in October 1958. This engine, designated the XLR-115-P-1, now under development for NASA, is conservatively rated at 15,000 lb thrust, with growth capability beyond 20,000 lb.

In the Centaur development and on previous projects, Pratt & Whitney Aircraft has utilized several million gallons of liquid hydrogen in the development of propulsion systems. This large-scale use has shown that liquid hydrogen can be safely stored, transferred, and used with existing cryogenic technology, and has permitted the development of hydrogen pumps capable of producing 1100-psi pressure rise.

Because of the high expansion ratios desired for maximum specific impulse, specialized engine test facilities are required to minimize flow separation in the nozzle. Four engine test stands equipped with exhaust diffusers and steam ejectors have been constructed by Pratt & Whitney Aircraft to implement this engine development. This test stand exhaust system provides near space conditions for starting and running the engine.

On the Mark

Although the details of the Centaur program are still classified, the photo on page 76 witnesses that the development of the first major hydrogen rocket engine is all but a reality, and its promise in space projects ready to be fulfilled. ♦♦

Rocket Test Stand Challenge

(CONTINUED FROM PAGE 29)

stand is that this instrument becomes a part of the system it is measuring during a test, thereby directly affecting the data obtained from the test. As the types of measurements become more highly refined, the difficulties of separating the effects of the test equipment from the actual response of the test item by itself multiply considerably. For instance: A number of studies have been made of the effect of the mounting device for a liquid-propellant engine on the stability of combustion. Another example is found in the efforts to determine the random characteristics of the oscillatory component of thrust and, in turn, to determine the vibration environment it imposes upon the rocket structure and the systems it carries. Here, again, the influence of the supporting structure is great and it is difficult to subtract from the directly obtained data.

Another challenging type of measurement is that of determining the instantaneous direction of thrust and its rate of change, particularly in engines with thrust-vector control or with multinozzle configurations. Aerojet-General has used a type of stand, designed by Aetron, in which the rocket engine is suspended in a force balance which measures six components of the combined gravity and thrust vector. This type of stand, while satisfactory within certain limits for obtaining static-testing data, is quite limited for determining the rapidly varying dynamic information more often desired.

One of the most stimulating design problems is that of devising captive missile tests for determining the dynamics of control systems and the vibration environments of the missile system. Aetron has participated in much of the work which has been done in this direction, such as a test stand at Edwards AFB for the Thor missile, a stand at the Douglas-Sacramento site also for the Thor, and a stand at Lockheed's Santa Cruz site for the Polaris. These test facilities (all in California) have increased successively in the degree of design sophistication, especially with the regard to the number of degrees of freedom of motion by the captive missile. The Polaris facility was designed with the intention of allowing limited motion about the pitch and yaw axes and in vertical and horizontal oscillatory translation. The missile was restrained from escape and from rotation about the longitudinal axis. There are limitations to the maximum acceleration a missile can stand; and the center of gravity, about which pitch and yaw will occur in freeflight, moves several feet during a firing. Also, the firing must be made nozzle-down. These restrictions, in addition to insuring that the missile does not escape during the firing, make the problem of minimizing test-stand influence on simulated free-flight conditions a highly technical design challenge.

Growing Pains

It would not be fair to ignore some of the retarding factors encountered in test-stand design activities. While it is true that the industry, in its growing pains, is freeing itself of these bothersome and seemingly unnecessary problems, some of them remain to the disadvantage of the customer, the designer, and the taxpayer. All of them tend to prolong the time of contract

initiation, completion, and cost. They include the extended period of time it takes the planners to decide what they want to do, the formalities of invitations to propose, proposals, preliminary design, design criteria, and final design. The concrete and steel men point out why the planners should have something different, and the test and instrumentation people make most plausible pitches why both groups are wrong. Rolls and rolls of drawings are scrapped at the eleventh hour in what is charitably called a "re-direction of program scope." And all these preliminaries occur before the first yard of concrete is poured or the first line is run for site development.

Further delays include the time it takes for concrete to cure, for steelmen to bolt and weld, for rain to stop, for high winds to subside, for ground water to be pumped, for personnel problems to be solved, and for adjustments to the thousand-and-one annoyances the designers were sure would not be repeated. More pacesetting factors are found in the delayed delivery of hardware, in the time required to find out which wires somehow got to the wrong terminals, which piping flanges leak, and which valves won't open or won't shut.

Solutions Possible

It is acknowledged that all of these annoyances, such as some inflexible contractual procedure, weather conditions, and honest mistakes of minor nature, cannot be eliminated completely. But in certain areas of planning and design, our company has eliminated a number of the problems through the type and scope of its organization and mode of operation. This is not to imply that Aetron is the only organization which can provide the ultimate in design performance, but to point out some methods of operation which, through 12 years of experience and participation in practically every major missile project in the free world as a prime or subcontractor, contribute substantially to the reduction of performance time and costs.

Our personnel are selected with high consideration not only for ability and experience in their respective fields of civil, mechanical, structural, chemical, electrical, and electronic engineering or other specialized fields, but also for qualifications of having a reasonable understanding of the other fellow's problems or at least the ability to speak the other fellow's language. Thus, we expect, differences of opinion are cut to a minimum, design problems are simplified, and time is saved. Further time is saved by starting hard-

Line of Titans

This, the first photo released of the Titan production line at Martin-Denver, shows first and second stages of the long-range intercontinental ballistic missile in various phases of assembly.

ware procurement long before final design is reached. The preparation of bid packages with specifications and drawings for the construction contractors is started as soon as possible. Our contract and customer relations divisions maintain close liaison at all times to minimize possibility of delays which might result from change orders, misunderstandings with the customer, subcontractors, or vendors, and to control budgetary expenditures of design time and material. Field representatives, under immediate supervision of the project engineer, form an important link of constant onsite inspection and communication for smooth progress of the project. Other supporting divisions and departments within Aetron cooperate as a unit to provide the many accessories to contract performance, such as the preparation and publication of progress reports, maintenance of proper security measures as required, public relations, and the handling of transportation and communications.

Aetron's Contribution

Aetron has engaged in the design and the supervision of construction of some 32 test stands ranging in initial thrust ratings from 100 lb to 6 million lb. With few exceptions, each stand differs from the others in purpose and design. In most instances, the test stand itself was but a part of an entire test-facility complex. The site locations are widely separated, and include Aerojet's own initial proving grounds at Azusa, Calif.; the Rocket-Engine Test Station at Edwards AFB, Calif.; the Lockheed test facilities at Santa Cruz; the Douglas Aircraft facilities at Patrick AFB, Fla., and at Sacramento, Calif.; the Martin Co.'s "Titan" stands near Denver, Colo.; Rocketdyne's production test facilities at Neosho, Mo.; missile-system test stands at Redstone Arsenal; and the well-known \$150-million manufacturing and test complex at Sacramento, Calif., the largest complex of its kind in the free world.

Possibly indicating the shape of things to come, and one of the most interesting test-stand design projects undertaken by Aetron, is Test-Stand 1-B and Supporting Facilities for Edwards AFB. This stand ultimately will accommodate the static firing of rocket engines with a total thrust of 6 million lb, although initial construction will provide for simultaneously testing two engines of $1^1/_2$ million lb of thrust each. An artist's sketch of this stand appears on page 28.

The foundation, as well as the deflector-apron supports for the ultimate capacity rating of the stand, will be a part of the initial concrete construction. The steel superstructure, which will support the propellant "run" tanks and the test-engine mounting device, will be bolted to steel bearing plates on top of the concrete base. These plates will be anchored to the 12,000-cu-yd mass of concrete by high-tensile steel cable which will be pretensioned to minimize deflection during firings. The concrete base portion will have an over-all height of approximately 125 ft, and the initial firing opening for the jet flame at the deck level will measure 67 x 29 ft. Strain gauges will be located at critical stress points throughout the concrete structure for recording the effects of dynamic thrust loads.

Directly behind the stand, and separated by a 20-ft-wide pipe and conduit space, will be a two-story heavy-concrete support building for maintenance shops, equipment rooms, parts storage, and the instrumentation-and-control terminal room. The top of this building will provide access to the deck level of the test stand.

Test Stand 1-B Features

A 780-ft underground tunnel will connect the test stand to an existing control station. The tunnel will contain cables comprising 600 circuits of standard conductor and concentric lines for acquisition of not only engine-performance data but test-stand stress and strain effects and flame-deflector operation. While there will be 600 circuits for instrumentation and control purposes, more than 600 transmissions of information may be accomplished simultaneously by means of modulated carrier systems on some circuits. This is in keeping with economies, mentioned earlier, by which as much data as possible is obtained from a single firing in view of the high costs of firings. More than one sample of the same data would be obtained from further tests of the same item only for purposes of determining repeatability.

The test stand complex will be provided with two separate water systems. One system will deliver deluge and domestic water from a 400,000-gal storage tank with associated pumping equipment, and the other system will supply water for the flame deflector. The latter system, for the initial test-stand capacity, will deliver 75,000 gpm at high pressure through a 54-in.-diam supply line of steel pipe.

The scope of this project also includes extensive storage and transfer systems for liquid oxygen, fuel, and high-pressure nitrogen gas. All water, gas, and propellant systems will be designed to be compatible with existing systems, since certain portions will be used in conjunction with existing equipment for another test stand.

In addition to the specialty items mentioned, the design will provide for a major electrical distribution system, test-warning and communication systems, access roads, and parking areas. The electrical system includes transformers, switchgear, and transmission lines to supply power for the various load areas. The largest single power-demand will be for the deflector-cooling pump station, which will have an initial pump rating of 6000 hp.

Contract completion dates were established at 90 days for the submittal of "preliminaries" and 150 days for the submittal of project material. Intense coordination was mandatory, because

criteria were not definite and all decisions had to be approved by the Corps of Engineers (LADO and SPD), Edwards AFB, ARDC, and Rocketdyne. Coordination meetings held weekly during the first two months of the project were attended by representatives of all agencies concerned. This coordination was conducted in such a manner that it resulted in completing the preliminaries two weeks ahead of schedule, and this gain in time was retained through the completion of project material.

A major factor contributing to the successful performance of the contract was the full cooperation received by representatives of the Corps of Engineers in accelerating design reviews and providing necessary data and criteria.

The Final Package

The final design package includes 313 drawings, of which 208 were prepared by Aetron, 62 by the Sverdrup & Parcel Engineering Co. (selected by Aetron as a subcontractor for certain civil and structural portions), and 43 by the Corps of Engineers.

Even to the seasoned engineer, future requirements for test facilities are somewhat awe-inspiring. The problems are enormous. Many of the parameters which will have to be considered are unknown. Future values of many parameters, compared to those of the present, will be far offscale, the tables at hand not even going that high or low. Test facilities and instrumentation (Remember that test facilities *are* instruments!) always lag behind design and research requirements for rocket propulsion and guidance systems. Wider ranges and higher accuracies are demanded. And with more highly compressed time schedules in the offing, the pace will accelerate even faster.

Research and development are now proceeding toward advanced missiles, space navigation, high-temperature resistant materials, ultrahigh-speed gas dynamics, and ionic and nuclear propulsion systems, with particular emphasis on higher and higher thrust ratings. Where all of this will lead provides an interesting and exciting study of the master plan for spaceflight development.

The test facilities for the future must be planned now if the anticipated rate of progress is to be maintained. We do not know what the specific requirements of the future will be, but we can be very sure that the pattern will be one of constantly increasing demands which will consist of unprecedented challenges to the designers and builders of rocket test facilities. ♦♦

People in the news

Medaris Bows Out

Maj. Gen. J. B. Medaris (left), recently retired commander of the Army's missile and space programs, happily receives two of the nation's highest military honors—the Distinguished Service Medal, Oak Leaf Cluster, and the Legion of Merit, Oak Leaf Cluster—before bowing out. Gen. Medaris has been elected as board chairman of Electronic Teaching Laboratories, Washington, D.C., fulfilling an ambition to find a place in education upon his retirement from the Army after 37 years of active service.

APPOINTMENTS

Milton B. Ames Jr. has been named deputy director of NASA's Office of Advance Research Programs; **Nicholas E. Golovin** deputy to associate administrator Richard E. Horner; and **David Keyser,** chief Congressional liaison officer.

Col. John G. Zierdt, AOMC chief of staff, has been appointed deputy commander of the Army Rocket and Guided Missile Agency, in charge of the Army's antimissile and space defense programs. **Col. Thomas W. Cook** succeeds Col. Zierdt. **Nils L. Muench** and **William Walton Carter** have joined ARGMA and AOMC, respectively, as chief scientists.

Francis Harrie Richardson has been appointed technical director of AF Flight Test Center at Edwards AFB, Calif.

Jacob P. Den Hartog has joined AFMDC's Central Inertial Guidance Test Facility at Holloman AFB, N.M., as guidance test manager.

At Rocketdyne, **J. E. Thompson** has been upped to director of facilities, and **J. P. McNamara** has been named manager of the newly created Liquid Propulsion Operation, Canoga Park. Heading the five major activities within LPO are: **P. R. Vogt,** chief engineer, LPO; **Ross Clark,** Canoga plant manager; **E. A. Wright,** Neosho plant manager; **R. L. Heath,** manager of quality control, and **J. A. Broadston,** manager of logistics. **Ivan E. Tuhy** has been appointed section chief of Rocketdyne's solid systems projects in the Advanced Design subdivision, Canoga. **C. G. Zlomke** has been made chief of engineering's design and development section at the McGregor plant.

STL has appointed **Eugene V. Thatcher** and **William R. McMurran,** respectively, associate heads of the Atlas and Titan Project Offices of Flight Test Operations.

Lloyd R. Everingham has joined Ryan Aeronautical as director of its space laboratory, with responsibility for operating the new subsidiary, Aerolab Development Co., Pasadena.

H. Norman Abramson has been made director of applied mechanics at Southwest Research Institute.

George A. Siegelman has been made director of research and engineering for the Energy Div. of Olin Mathieson Chemical Corp.

Cornell Aeronautical Laboratory, Inc., has named **T. F. Walkowicz** a board member.

Bernard H. Paiewonsky has been promoted to senior research engineer at Aeronautical Research Associates of Princeton, Inc., in charge of studies of space-vehicle motion and control.

The newly established Electronics Div. at Martin-Baltimore will be headed by **John J. Slattery. Joseph M. Dukert** has been named manager of information services for the Nuclear Div.

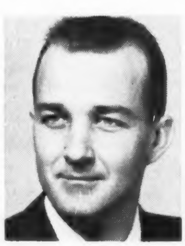
James D. McLean has joined General Dynamics Corp. as president of its Stromberg-Carlson Div., and will also serve as senior vice-president and member of the board of management of the parent company. At Convair Div., **Gene L. Armstrong** has been promoted to senior project engineer for airborne systems on the Atlas missile program.

At Bendix Aviation, directors **George E. Stoll** and **A. P. Fontaine** have been elected executive vice-presidents. **Charles M. Edwards** becomes assistant to Fontaine. In other appointments, **Russell D. O'Neal** has been elected vice-president, engineering. **Roy S. Sandstrom** will succeed him as general manager of the Systems Div.-Ann Arbor, while **L. B. Young** will take over Sandstrom's former post as assistant general manager.

Arthur C. Omberg has been named assistant group executive of the Bendix-Mishawaka Div., formerly known as Bendix Products Div.-missile section, and to supervise the Hamilton (Ohio) Div. In addition he will serve as a member of a technical management group under direction of A. P. Fontaine, dealing with space activities. **J. P. Field** will be Omberg's assistant. Also at Mishawaka, **P. R. Wendt** has been named manager of quality and reliability, and **William Solomon,** chief airframe engineer. **G. A. Rosselot** has been made assistant general manager and associate director of the Research Laboratories Div., and **S. B. Smith,** assistant director, engineering, Bendix Products Div.-South Bend.

George B. Shaw has been upped from manager of operations, Nuclear Products-Erco, to head the new ACF Industries Electronics Div., resulting from the merger of the Avion and Nuclear Products-Erco divisions. **Robert Young** will be assistant general manager; **W. T. Whelan,** director of R&D; **M. L. Bond,** manager of special products; and **M. M. Millette,** manager of the Riverdale, Md., plant.

At Aerojet-General, **Jerome C. Joerger** has been appointed manager of



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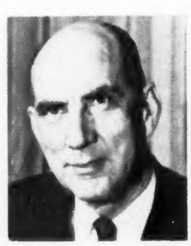
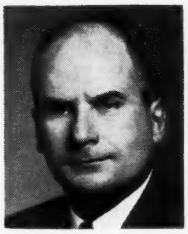


Shaw

Joerger

Kowallis



Huggett

Downing

Kaplan

Hueter

Leng

the Aeronautical Div.; **William H. Gordon,** manager of plant engineering, replacing **Robert H. King,** who becomes manager of ordnance manufacturing; and **Col. Richard G. Thomas** (USA-Ret.) a technical specialist in the Long-Range Planning Div. at Monterey. **Edward L. Rucks** will head the new Structural Materials Div., which combines the Structural Plastics Div., formerly under Rucks, and the Material Dept.-Azusa Operations, formerly under **Lawrence L. Gilbert,** who now becomes assistant manager for metals development.

Capt. Victor H. Soucek (USN-Ret.) has been appointed manager of special projects for Sanders Associates, Inc.

O. K. Kowallis has been promoted from chief engineer to director of research at Wiancko Engineering Co., while **Robert L. Nakasone** succeeds him as chief engineer.

George A. Zink has been appointed director of process development for GM's new Defense Systems Div.

Alfred H. Canada, manager of advanced engineering physics for GE's Advanced Electronics Center, Ithaca, N.Y., has been selected to fill a one-year appointment on the analysis staff of the Institute for Defense Analysis, Washington, D.C.

Clayton M. Huggett has been appointed director of research for Amcel Propulsion, Inc., subsidiary of Celanese Corp. of America.

Henri Busignies, former president of ITT Laboratories, has been named vice-president and general technical director of the parent ITT Corp.

Frank M. Wilson has been appointed manager of the fluid dynamics division at Lockheed's Georgia Div. **R. B. Ormsby** will manage the newly established Aerospace Technology Dept. there; **William C. Strang,** formerly staff engineer, subcontracting, Convair-Pomona, has been made manager of operations for Lockheed Missile System Div. at the U.S. Naval Weapons Annex, Charleston, S.C.

W. S. Johnston has assumed over-all responsibility for all airfoil operations of the Tapco Group of Thompson Ramo Wooldridge.

Airborne Instruments Laboratory has announced the appointments of **E. G. Fubini** and **G. C. Comstock** as vice-presidents in charge of the new Research and Systems Engineering Div. and Electronic Systems and Techniques Div., respectively.

Edward P. Fleischer has been made assistant director of the Electro Mechanical Instrument Div., at Consolidated Electrodynamics Corp.

George V. Woodrow Jr. has been appointed director of weapons systems engineering for Philco's Government and Industrial Group. In the Research Div., **Allen C. Munster** has been named director of research, plans and programs, and **Lawton M. Hartman,** manager of technical planning, as well as a member of the division's management and operations committees.

Beal P. Moore has joined Stavid Engineering, Inc., as an engineering consultant in the Airborne Electronics Dept.

James B. Williams has been appointed vice-president, engineering, at Electronic Communications, Inc.

Continental-Diamond Fibre Corp., a subsidiary of The Budd Co., has appointed **W. M. Lair,** director, and **A. H. Haroldson,** associate director, at its new R&D center in Newark, Del.

J. Robert Downing has been elected president of Space Recovery Systems, Inc., El Segundo, Calif. He had formerly served as director of the R&D Div. of Cook Electric Co., Chicago.

Paul Kaplan has joined T.R.G., Inc., Syosset, N.Y., as chief hydrodynamicist.

Bert Fein has been appointed director of manufacturing at Avco's Crosley Div.

Seymour L. Blum, formerly head of Raytheon's Ceramics Section, has been appointed manager of the High Temperature Materials Dept. in the Research Div.

Earl Q. Bowers and **Richard J. Dempsey** have joined National Cash Register, Electronics Div., as design development engineers.

Royal Jackman, Northrop Norair Div. chief, Engineering Laboratories group, has been elected chairman of the AIA Aerospace Research and Testing Committee.

Robert C. Langford has been appointed director of engineering, Newark operation of Western Instruments Div. of Daystrom, Inc., succeeding **Francis X. Lamb,** formerly vice-president, engineering, who has been named engineering consultant to J. F. Degen, vice-president at Newark operations.

Fred Covarrubias becomes applications engineer in the Marketing Div. of Data-Control Systems, Inc.

Theodor F. Hueter has been named manager of the Seattle Development Laboratory of Minneapolis-Honeywell Regulator Co., in charge of lab work in sonar, underwater ordnance devices and systems, and radar and communications.

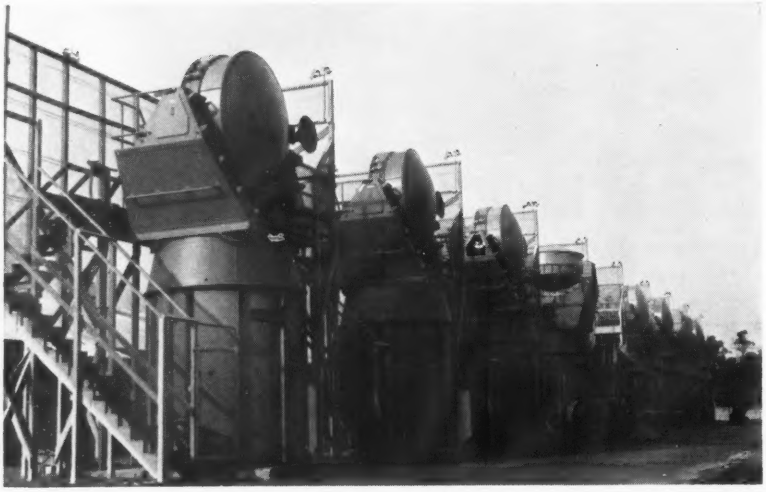
Owen E. Cunningham is director of the new R&D Laboratory established in Washington, D.C., by the Link Div. of General Precision, Inc.

Richard B. Leng has been named vice-president in charge of Packard Bell's new Defense and Industry Group.

J. H. Day Co. has announced the promotion of **Ray D. Allison** from chief engineer to general manager; **Robert Miller**, to sales manager; and **Jack L. Diltz** to product and market research engineer. **Martin Miller,** as vice-president, will assume staff duties, including over-all planning for the division.

Peter J. Schenk, immediate past president of the AF Assn., has been named executive vice-president of The Mitre Corp., Lexington, Mass.

(CONTINUED ON PAGE 93)



Bleacher Seats

Looking like giant mechanical men, these nine SPG-55 radars sit on the range-testing line at Sperry Gyroscope's MacArthur Field, Long Island plant, where they are checked for accuracy, reliability, and performance before delivery to the Navy. The SPG-55 radar automatically acquires, locks-on, and tracks a target and in the same operation guides a Terrier missile against it.

Report on COSPAR

(CONTINUED FROM PAGE 25)

W. Porter of GE, U.S. delegate to COSPAR and a member of the National Academy of Sciences Space Science Board; Hugh Odishaw, executive director of the Board; Joseph Kaplan of the Univ. of California, chairman of USNC-IGY; Harold C. Urey of the Univ. of California and Joshua Lederberg of the Stanford Univ. School of Medicine, both Nobel prize-winners; and Abe Silverstein and Homer E. Newell Jr. of NASA.

The five-man Russian delegation was headed by Anatoly A. Blagonravov, a member of the Presidium of the Soviet Academy of Sciences, and one of the Soviet scientists who attended the ARS 14th Annual Meeting in Washington, D.C., last November, and S. N. Vernov of the Upper Atmospheric Physics Division of the Soviet Academy of Sciences.

At the moment, there are 16 countries whose scientific institutions, i.e., National Academies, are now represented in or have expressed an interest in participating in COSPAR. These are Australia, Belgium, Canada, Czechoslovakia, France, West Germany, Italy, India, Japan, the Netherlands, Norway, Poland, South Africa, the U.K., U.S.S.R., and U.S.

In addition, 10 international scientific unions are represented in COSPAR, among them the International Astronomical Union, Union of Geodesy and Geophysics, Union of Pure and Applied Chemistry, Scientific Radio Union, Union of Pure and Applied Physics, Union of Biological Sciences, Union of Theoretical and Applied Mechanics, Mathematical Union, Union of Physiological Sciences, and Union of Biochemistry.

Under the new COSPAR charter, approved in December (February *Astronautics*, page 27), the committee's activities will be directed by an executive council, made up of a president, a vice-president nominated by the U.S., and two members chosen from a list drawn up by him; a vice-president nominated by the U.S.S.R., and two members selected from a list made up by him; and representatives of all the scientific unions.

The slate of officers elected at Nice is headed by H. C. Van de Hulst of the Netherlands, representing the Intl. Astronomical Union, who is president of COSPAR. The American vice-president is Dr. Porter, representing NAS; the Russian vice-president, Prof. Blagonravov, representing the Soviet Academy of Sciences. Other elected members of the council are E. Bucara of Czechoslovakia, representing the Czech Academy of Sciences; H. S. W. Massey of the U.K., representing the Royal Society; M. Roy of France, representing the Intl. Union of Theoretical and Applied Mechanics; and W. Zonn of Poland, representing the Polish Academy of Sciences.

Working in a scientific, rather than political, atmosphere, members of COSPAR and its working groups mapped out a wide area of space research activities in which international cooperation appears feasible. At one of the first sessions, for example, Russia agreed to make available orbital elements of their satellites as an aid to international cooperation in observation programs.

Makeup and responsibilities of the three COSPAR working groups, established on a provisional basis prior to approval of the new charter, were decided upon at the meeting. The three working groups, and their chairmen, are: Tracking and Telemetering, headed by V. A. Ambartsumian, Chairman of the Astronomy Division of the Soviet Academy of Sciences; Scientific Experiments, headed by J. Bartels, Geophysikalisches Institut, Göttingen, Germany; and Data and Publications, headed by A. P. Mitra of India.

Resolutions passed offered the services of COSPAR to the newly formed UN Committee on the Peaceful Uses of Outer Space; called for continuing COSPAR cooperation with the International Telecommunications Union and coordination of the demands for radio frequency spectrum allocations for space research; asked countries launching satellites and space vehicles to release telemetering codes and calibrations where practical; stressed the need for a continuing survey of the orbiting components of satellites; and recommended that a revised list of IGY satellite tracking stations be drawn up and made available to all interested workers.

Additional Resolutions

Additional resolutions confirmed the week of Sept. 16–22, 1960 as an International Rocket Interval, and recommended that meteorological rocket soundings be undertaken by all nations in a position to do so during the quarterly meteorological world intervals of 1961, with special emphasis on the January and October periods; called for experiments on decontaminating and sterilizing spacecraft; pressed for additional satellite and space-vehicle prelaunch and launching information, as well as precise data on orbital elements and orbits; recommended that the World Days AGIWARN network, utilized during IGY for rapid communication of information needed for tracking and other observational purposes, continue to serve for such purposes under the name of SPACEWARN; and called for distribution to COSPAR members as soon as practicable of complete information on scientific space experiments.

Another important resolution urged

that consideration be given to the potential desirability of international cooperation in data reduction and analysis.

Delegates to the Symposium were informed that the U.S. intends to launch at least eight scientific satellites and two space probes in its civilian space program during 1960, along with a geophysical probe and a number of meteorological rockets. Included in the proposed satellite launchings are three radiation belt experiments; experiments to determine ionospheric properties and electron densities; an ionospheric beacon experiment; gamma ray astronomy and solar spectroscopy experiments; two meteorological experiments (Project Tiros); a communications experiment (Project Echo), utilizing a 100-ft inflatable sphere; and a geophysical probe utilizing the Scout vehicle.

Russian delegates to the meeting also presented a good deal of information about future plans in their report to COSPAR, with Prof. Blagonravov indicating that the U.S.S.R. was planning a broad investigaiton of cosmic radiation preparatory to manned spaceflight experiments, and expects to launch satellites carrying plants and highly organized living organisms in the not-too-distant future. The Russians also provided more information about their meteorological rocket launchings than at any previous meeting, giving complete information as to launching sites, exact time of firing, and data obtained. The report went all the way back to 1957, and also covered Soviet satellites and lunar probes.

In discussing future Soviet plans, Prof. Blagonravov noted that experiments would fall into three general areas—continued investigation of the upper atmosphere and near space, further exploration of the moon, and preliminary investigation of the nearer planets, specifically Mars and Venus.

Among the other countries reporting on future plans to COSPAR were France, which announced it would launch 20 Véronique sounding rockets this year, and the U.K., which is working on Scout payloads with NASA and on adaptation of some of its military rocket vehicles for satellite launchings. Both France and Australia indicated an interest in collaborating with the U.S. on satellite experiments, while Italy discussed with the U.S. the possibilities of firing sounding rockets from Wallops Island.

The Space Science Symposium was devoted largely to a full-scale report on IGY activities throughout the world. Coming a full year after the official closing of IGY, it presented for the first time a complete rundown on IGY rocket and satellite research. While some of the material in the American papers had already been presented earlier before U.S. audiences, much new data was offered, and the meeting provided the first opportunity for an international discussion of such data.

In all, a total of 14 sessions were held—two each on the earth's atmosphere, the moon and the planets, tracking and telemetering, the ionosphere, and solar radiation, and one on meteorites, and three on cosmic radiation and interplanetary dust.

Papers Presented

U.S. delegates to the meeting presented more than 50 papers, while nine papers were given by the Russians. These were: "Upper-Atmosphere Structure Parameters According to Investigation Data Obtained on Rockets and Satellites in the U.S.S.R. during IGY," by S. M. Poloskov; "Terrestrial Corpuscular Radiation and Cosmic Rays," by S. N. Vernov and A. E. Chudakov; "Radiation Measurements during the Flight of the Second Soviet Space Rocket," by Vernov, Chudakov, P. V. Vakneov, Yu. I. Logachev, and A. G. Nikolayev; "Cosmic Ray Investigations by the Second Cosmic Rocket Landed on the Moon," by L. V. Kurnosova, Logachev, L. A. Rasorenov, and M. I. Fradkin; "Measuring the Magnetic Fields of the Earth and Moon by Means of Sputnik III and Space Rockets I and II," by S. S. Dolginov, E. G. Eroshenko, L. N. Zhusgov, N. V. Pushkov, and L. O. Tyurmina; "Photographs of the Reverse Side of the Moon," by A. A. Blagonravov; "On Corpuscular Radiation of the Outer Atmosphere," by V. I. Krassovsky; "Results of Research on Meteoritic Dust with the Help of Sputnik III and the Cosmic Rockets," by Nazarova; and "Cosmic Rays Emitted by the Sun," by A. N. and T. N. Charakchian and V. F. Tulinov.

The sessions dealing with the moon and the planets produced the most speculative papers presented at the meeting A paper by M. Calvin and S. K. Vaughn of the Univ. of California at Berkeley on the subject of extraterrestrial life discussed some organic constituents of meteorites and their significance for possible extraterrestrial biological evolution, while Dr. Lederberg, in the course of a discussion on contamination of other planets, touched on the problem of how to prevent astronauts returning from such planets from contaminating earth.

The complete proceedings of the Symposium will be published by COSPAR in the near future. Hilde K. Kallman of UCLA, scientific secretary for the meeting, is editing them. ♦♦

JPL Continues Vega 6K Controlled-Thrust Engine

Although NASA canceled the Vega project, it continues to support JPL's development of the 6000-lb-thrust storable-liquid engine for upper-stage applications in space vehicles.

Static firings of this "6K" engine have recently been made on a new JPL stand at the Edwards Test Station in Calif.

The photo shows part of the stand, and in particular its spherical stainless-steel propellant tanks, which were designed and fabricated by Standard Steel Corp., Los Angeles, Calif. Both tanks are ASME Code-designed and -constructed for an operating pressure of 500 psi. The 6K engine employs nitrogen tetroxide and hydrazine as propellants.

Propellant tanks for JPL's new 6K-engine test stand at Edwards Test Station just before installation in the facility's 43-ft-high framework.

Billion Light Years

(CONTINUED FROM PAGE 33)

been made of the radio radiation on a wavelength of 3.75 cm coming from the central regions of our own galaxy. There is so much dust and obscuring matter between earth and the galactic center that observations with optical telescopes cannot be made into the depths of the Milky Way. The use of short radio waves allows quite detailed observations of the galactic center. The results show a very interesting group of four radio sources around the galactic center. Further work should reveal much about the motions of matter in the core of our galaxy.

On a more speculative level, some time ago it was realized at NRAO that the 85-ft dish together with a parametric amplifier or maser receiver could detect radio waves coming from very great distances. If within about 9 light years from the earth there were a radio transmitter system similar to the ones that have been used on earth to make radar reflections from the planet Venus, and this system radiated toward the earth, it might just be possible to detect the existence of this transmitter.

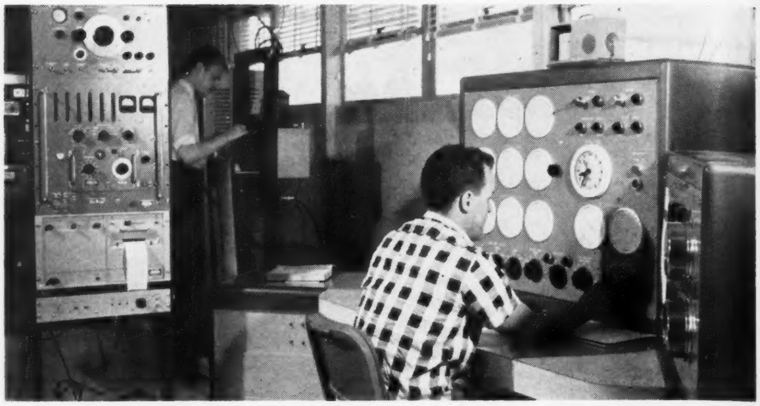
The Near Stars

There are very few stars within 9 light years from the earth and of these not all could possibly have planets rotating around them. Nevertheless, faint as the possibilities are, the 85-ft telescope will soon be used to examine two nearby stars, in the hope that one of the stars has a planet, then that this planet has reasoning life on it, and that this life is beaming messages toward earth.

Also under study with the NRAO telescope are the sun and its interaction with the earth, the creation and destruction of stars, the outer atmosphere, and the space immediately surrounding the earth.

Tracking celestial objects with the NRAO telescope is simplified because of the unit's equatorial mounting. The telescope's axis is parallel to the axis of the earth and turns at a constant rate of speed—one revolution per day. This compensates for earth rotation. Once a celestial object enters the telescope's field of view, it remains in that field as long as rotation around the unit's equatorial axis is provided at the proper rate.

Although Green Bank's Deer Creek Valley offers a relatively mild climate and is not subjected to extremely high winds, each of the telescope's three legs—spaced 35 ft apart in a triangle—is anchored in 1200 tons of concrete.



Controls and receiving equipment are in a 24- x 36-ft house just 25 ft from the telescope's base. Above, Heim Hvatum (left) of Sweden and Omar Boyer, telescope operator, work on a celestial-tracking problem. At the left is an electronic counter which converts received radio emissions into digital form.

The telescope operates with precision in winds up to 45 mph and will withstand wind velocities up to 120 mph.

The height of the radio telescope from base to focal point—with the reflector in zenith position—is 110 ft. Steel framework supports the polar and declination shafts and gears and the solid aluminum reflector on which surface accuracy is $^1/_8$ in. at all points to a true paraboloid. The polar shaft is set at 38 deg, 26 min latitude and covers 12 hr in east-west, horizon-to-horizon move. Range of the declination drive is from 51 deg, 44 min north, through zenith, to the southern horizon. A quadripod supports the electronic equipment at the focal point, 36 ft from vertex of the 6000-sq-ft reflector. East and west huts, attached to the reflector's back, house receiving equipment and cable terminations.

Operating power for the telescope is supplied through 4160-v lines. This voltage is transformed to 440, 220, and 110 v. Counterweights— 136,000 lb on the polar gear and 45,000 lb on the declination gear—balance the entire mechanism so that no great amount of power is required to drive either gear. Voltage is 220 to a 20-hp motor powering the polar axis and its gear, while only a 12-hp motor is required for declination drive.

Controls for the equatorially mounted telescope are in a 24- x 36-ft structure that is only 25 ft away from two legs of the highly maneuverable antenna unit. These controls provide the telescope operator with hour angle, sidereal time, right ascension, and declination position indicators; polar axis, declination, and brake switches; warning lights for declination and polar limits, and power; and emergency power "off" and "reset" buttons. Sensitivity of the electronic receiving equipment to temperature changes requires a constant temperature of 70 F in the control room.

In operation, the telescope's accuracy allows reception of radio emissions in wavelengths ranging from 10 meters to as low as 3 cm, and is capable of simultaneous reception of three frequencies. The radio signals are not characterized by easily identifiable features, such as voice modulation, but are generally constant hisses or noises. They are distinguishable from man-made interference only because celestial signals originate in particular places in the heavens. Radio emissions from space bounce off the reflector surface into the focal point and are transmitted by cable to receivers in the control room. After being recorded in graph and digital form, the signals are translated into measurements of physical quantities connected with observed objects.

Radio astronomers at Green Bank are using three receivers—one in the 8000-mc band, another in the 400-mc band, and the third, which is a hydrogen-line (21-cm) receiver, with a pickup area ranging from 1170 to 1430 mc. A fourth receiver, scheduled for use in the near future, will add to this already wide variety of frequency ranges. ♦♦

Unusual Chemicals

The Hummel Chemical Co., Humchem, N.Y., has available research quantities of the following unusual chemicals: Hexanitroethane; trinitromethane, trinitroethanol, tetranitromethane, ammonium nitroform, potassium nitroform, hexanitrodiphenylamine, trinitrophenylmethylnitramine, nitration of amines to nitramines.

Missile market

By Jerome M. Pustilnik, Financial Editor

THE SHARPEST reaction in recent memory buffeted the stock market last month as persistent weakness in major steel and automotive shares led the Dow-Jones average 8.3 per cent lower. As the easiness spread to most other industrial groups—although numerous specialties resisted the downward pressure—missile industry securities plummeted 11.6 per cent, as measured by the Missile Index.

Such a severe decline puzzled many investors in light of glowing business projections in the financial sections of their newspapers. This is not as paradoxical as it may seem, for financial history offers many examples in which business activity and stock market prices move in opposite directions.

Nonetheless, it must be recognized there really is no such thing as a stock market. Instead there is a market of stocks; and the investment adviser, against a general background of high security prices, endeavors to select those issues that are relatively attractive. Stocks enjoying this attribute may fall into two broad categories: (1) Cyclical stocks which are at the right point in their cycle and (2) companies experiencing genuine growth. This column feels it is wiser to stress growth, because while it is always possible to be mistaken on timing, one will be rewarded reasonably soon with a growth stock.

Certainly there are many legitimate growth stocks, and growth industries. And new technologies offer the most valid growth areas, despite stock market weakness. Such is molecular electronics: One of the newest and most promising branches of solid-state technology, attractive at this time.

Component density of 50–100 million per cubic foot, e.g., in amplifiers smaller than a dime, are recent developments that signal this new concept's dramatic and far-reaching effects—even in an industry well known for its fast moving technology. Molectronic devices are essentially tiny blocks of crystalline silicon or germanium, which are now used in transistors, but their potential uses go far beyond anything yet conceived. They are significantly smaller than micromodules, which they very likely will replace, despite the fact the latter is their predecessor in the race for microminiaturization and is still largely in the development stage.

Many scientists believe micromodules are the last practical step in miniaturization where many connections are used. In fact, the soldering points connecting the electronic elements in many micromodules are usually larger than the elements themselves.

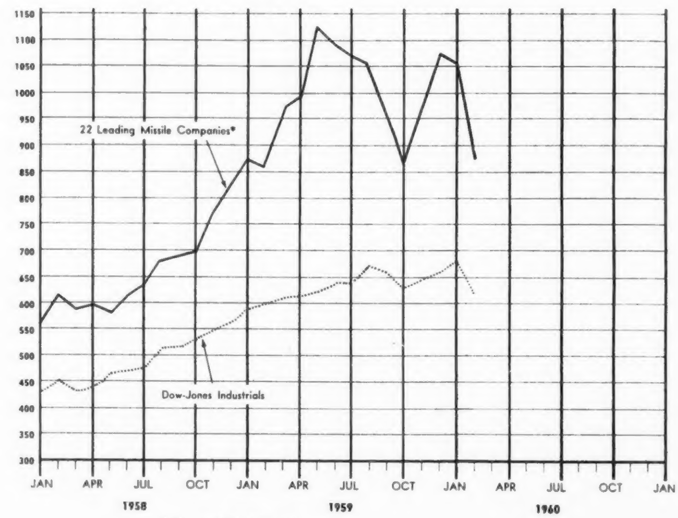
And it is these soldered connections which cause worry, for each soldered junction is a possible source of failure should the connection be faulty. In complex defense electronics systems, the possibility of failure is high because of the large number of such connections. But molectronic devices drastically reduce the number of soldered points in a system. Like building blocks, they can be piled one on top of another or placed end to end. All of the traditional components of a circuit can be eliminated in molectronics as well as most of the connections. Through their simplicity and tiny scale, molectronic devices appear to have a brilliant future although large-scale use is several years away at best. Initial uses will be in defense electronics systems, but industrial and consumer applications should follow swiftly.

Many major electronics firms are active in this technology, among them Westinghouse Electric, RCA, Texas Instruments, Motorola, American Bosch Arma, and Philco Corp. In England, a company named Plessy, Inc., has developed molectronic devices.

Philco, which could earn $1.00 a share from solid-state physics activities alone, in 1960, plus another $1.75–2.00 a share from home appliances, computers, and defense electronics business seems very favorably situated and a full report is planned for the next issue.

Now a word of caution. Because new technologies take on an aura of glamor and mystery about them, some gross misconceptions get born in the investment community, creating the substantial excesses which sometimes occur in the marketplace. A corporate name which includes the magic word "electronics" or any other technological term for that matter, does not guarantee an investor participation in a science-oriented company or in a new technology. To be certain, use this old technology—INVESTIGATE THEN INVEST. ♦♦

THE MARKET AT A GLANCE



*Index compiled June, 1955

	February 1960	January 1960	% Change	February 1959	% Change
Dow-Jones Industrials	623	679	−8.3	594	+4.9
Missile Index	875	1059	−11.6	856	+2.2

U.S.S.R. Radio Telescope

(CONTINUED FROM PAGE 32)

offices and plants.

Engineer D. V. Kovalevsky, the station's chief, has remarked on the large size of the new telescope. Its paraboloid is 22 meters in diameter, while its focal length is 9.5 meters. The mirror tips the scales at 65 tons. The weight of the entire telescope amounts to 380 tons. A team of engineers and technicians spent nearly two years assembling and adjusting the massive instrument.

According to researcher Salomonovich, this telescope has the highest resolving power of all the adjustable radio telescopes in the world. It can be laid on any point of the sky. The telescope is fitted with a special tracking facility which helps carry on prolonged observations of space sources of radio waves. Currently, the telescope is being used to investigate solar and lunar radiations. Several radio pictures of the sun and moon have been taken with it.

Associated with this telescope will be another, a cross-shaped radio telescope now being built under the supervision of V. V. Vitkevich (M.Sc., physics and mathematics). This will be the world's largest radio telescope. Each of its two arms will stretch for about a kilometer and stand 40 meters high. The antenna of the East-West arm will be made rotatable about its horizontal axis.

Radio astronomy has already enriched our knowledge of the universe with a series of discoveries of paramount importance. An advantage of radio astronomical investigations of the moon is that both its surface and subsurface layers can now be studied. The new radio telescope will help glean data on individual sections of the moon's surface.

Alexander E. Salomonovich, who helped plan the telescope, sits at the visual training station in its upper cabin.

Of no less interest will be observations of the radio waves emitted by Venus, which is always wrapped in dense clouds. These observations may establish for the first time Venus' period of rotation.

Radio pictures of the sun taken regularly with the new radio telescope are of important practical value. They may indicate a missing link between the processes that occur in the sun's active areas and some of the still mysterious phenomena on the earth.

Sources of Radio Waves

As promising are studies into the sources of radio waves to be found far beyond the confines of the solar system. Extremely interesting in this respect are the gaseous nebulae in our galaxy as well as the nebulae formed in the explosions of so-called "supernew" stars.

Recent years have seen a sharp improvement in the sensitivity of receiving equipment in the UHF and the SUHF ranges. As the new Soviet radio telescope operates just in these ranges, it will have unquestionable advantages over the largest foreign radio telescopes operating on the VHF band, as its resolving power will be substantially higher.

Also, as soon as the large cross-shaped radio telescope is completed for operation on very high frequencies, the possibility will be provided to investigate a huge number of radio-wave sources far beyond our galaxy.

These and other investigations will yield valuable information about the universe, which, supplemented with the data obtained with the aid of optical astronomy, will provide a better basis for cosmogoenic theories.

—T. Fetisov, *Izvestia*

Psycho-Social Problems

(CONTINUED FROM PAGE 31)

physical movement, disruptions of normal day-night and work-rest cycles, monotony, fatigue, etc.

These physical and mental stresses will often occur together and over relatively long times. During these times, the stresses may well act cumulatively to wear down the individual's resistance and resiliency.

An important confounding variable is social interaction between a small group, who will be in very close contact for an extended period of time. Assuming that there is a higher stress-induced susceptability to social disorganization and personality conflict, just one irritating individual can seriously affect crew morale and start a chain reaction of incidents. This might be called a Mother-in-Law-in-Space syndrome.

Not to be underemphasized is the fact that there will be no panic button to permit sudden egress or to stop the experiment part way through. Once aboard, all must continue the flight through a hostile environment until its termination. This could become a rather overwhelming psychological problem for a crew member.

Of great psychological importance is the probable difficulty in maintaining adequate communication with the earth. This is especially important in view of the poor prospects for escape, survival, and rescue in the event of malfunction or accident. Communication is also important for feedback on the progress of the mission and crew contact with the ground for morale and recreational needs.

Exactly what complications might result when a human crew is suddenly isolated in a sealed capsule? How would they react to knowing that they would, in a sense, be experimental subjects in a comparatively new

test, development, or exploration program to discover more about some distant hostile environment?

Human Reactions in Space

The following human reactions have been observed or described in situations which approximate, to some degree, the conditions likely to be encountered in relatively unsophisticated spaceflight.

Physical. There may be feelings of extreme boredom, tiredness, and fatigue. Even sleep may not be refreshing and the use of rest periods may be of little use in improving performance. There may be a strong need for exercise and physical motion. An intense desire for a variety of external sensory stimuli may also occur.

Social. Feelings of comradeship and esprit de corps may gradually disappear and be replaced by suspiciousness and hostility toward others. Withdrawal from the social group, social incompatibility, and the emergence of negative feelings may lead to the gradual dissolution of social controls.

Behavioral. Irritability, restlessness, exaggerated responses, and a tendency to either withdraw completely from situations or to go charging into them may develop. There may be an amplification of overt tendencies toward aggressive or passive behavior, with hostility expressed toward other individuals, equipment, and the mission itself. Speech difficulties, such as an inability to speak in a normal volume, and other regressive behavior, may appear. Greatly increased individual variability in the performance of tasks occurs even in the most normal-appearing individuals.

Intellectual. There may develop an inability to think clearly and coherently or to organize and direct thought processes on any given subject for a period of time; tendencies to drift off into highly personal and emotionally charged fantasy; loss of confidence in judgment, with doubts as to personal ability to discriminate between the truth or fiction of experience; an intense need to confirm the validity or acceptability of thought, judgment, and adequacy of response; a malleability and suggestibility which may approach the point of confabulation; and feelings of being mentally dull, unresponsive, and unable to discriminate.

Emotional. Feelings of isolation and prolonged uncertainty may give rise to a variety of symptomatic responses. Initial feelings of general anxiety may include unrealistic fears and a sense of personal inadequacy, which could lead to a whole gamut of emotional reactions. Feelings of oppressive monotony may be a prelude to withdrawal, depression, and even suicidal thoughts. The disorganizing effects of stress may lead to compulsive defenses, other neurotic behavior, and paranoid feelings. Confusion and panic may develop into unresponsiveness, visual distortions, hallucinatory or delusional material, and even disorganization in time and place. The effects of sensory deprivation on man have been recently described as even somewhat akin to schizophrenic reactions.

All these reactions are based on information obtained from a variety of sources, such as prolonged undersea or aircraft flights, survival experiences (i.e., shipwreck), penal and PW experiences, sensory-deprivation studies, and even a few laboratory simulation studies of anticipated spaceflight problems. Naturally, there was great variability in information, and extrapolation from such sources is quite inferential. No one can state with any assurance just what may occur in actual spaceflight. But the financial and other costs involved are so enormous that we cannot wait for post facto diagnoses of astronautic failures associated with inadequate human factors considerations.

The need for more elaborate and rigorous simulation studies is quite clear. Basic experimental studies, reports from analogous personal experiences, and what is generally known about the science of human behavior have all indicated that there are some important problem areas which merit the serious consideration of those planning manned spaceflight. It is apparent that more careful study and intensive research is urgently needed to provide adequate and timely information regarding human psychological capability to perform astronautic functions.

What Remedies?

If psychological problems do constitute a potential hazard for spaceflight, one might ask if anything could be done to alleviate or prevent them. At this time, we can only speculate on possible remedies and solutions because of the novelty of spaceflight, the difficulties involved in attempted simulation of spacelike conditions in an earthbased research installation, and the over-all sparsity of research which is directly related to the subject area. However, the following information is offered as a temporary expedient or possible guideline for future

thought and research action in this area.

It is not enough just to say that we should have careful selection of the astronautic crew, because selection infers that we have an adequate predictive basis upon which to predicate the choice of standards. True enough, we do have aircrew selection standards and much is known concerning psychological selection. Although the appropriateness of applying these past selection standards to the new space situation may be questioned, it does offer an immediate approach which could be supplemented by some broad-brush guesses as to what might be a good test for this situation.

Therefore, current crew selection might well be based upon such things as age, general physical condition, physical endurance, psychological and psychiatric evaluation, anthropometric measurements, educational and experience background, tolerance to high altitudes, exposure to temperature extremes, and resistance to vibration and acceleration.

There are, however, some specific questions which should be answered as quickly as possible in this regard. For example, in terms of the heterogeneity of the crew, what is the desirable mixture of crew members in terms of age, sex, experience, education, marital status, and socioeconomic background? What is the optimum number of crew members to reduce the feeling of isolation and lack of communication with the earth? In terms of an appropriate combination of crew personality factors, what are the desirable personality structures, dynamics, and nosological entities for various crew sizes, flight missions, assigned work tasks, and flight durations?

How to Train Astronauts?

Since it will be rather difficult to simulate spaceflight realistically or to anticipate crew performance requirements fully, to what extent can there be appropriate orientation, familiarization, training, or indoctrination of crew members? Exactly what kind of subject matter should be covered, and how long, intensive, or realistic should the training be? Would the added separation from home, family, and friends be worth any other benefits accruing from *very* realistic simulation or preflight preparation? Should some simulation or training time be required in submarine- or stratolab-type capsules fitted with prototype equipment? While full knowledge of the operating characteristics of the vehicle and associated equipment is highly desirable, how much crew capability should there be for detailed maintenance and repair? Finally, how can training effectively complement rewards used to initiate and sustain the strong motivation necessary to insure success of a flight mission?

On another tack, it has been suggested that the sleep-duty-recreation cycle should closely resemble our familiar one. An artificial day-night cycle is thought to be particularly important in the sleeping quarters. As far as crew size is concerned, this consideration seems to imply that the basic modular personnel unit for each primary work function on extended missions should be a set of three individuals, one for each shift. As to job assignments, there are several questions which should be considered.

Should there be a rigid assignment of tasks and responsibilities or some rotational plan to afford a measure of variety and flexibility?

Should there be some semblance of

military discipline or should there be a professional shirtsleeve atmosphere?

If it is believed that the crew members should be kept occupied rather than permitted to become inactive, to what extent will supposedly meaningful and significant work tasks be perceived as "busy work," and thus perhaps negatively influence the crew?

Personal Security

An important factor in the psychological environment of the crew is the general sense of personal security. This key psychological underpinning reduces the fear and anxiety which precipitate many psychological problems. A sense of personal security, for example, may be engendered by the following means: Adequate two-way communication with the base of operation; knowledge of the appropriateness of control actions and the on-going success of the mission; some capability of the crew for active participation during emergency action or repair; adequate safety factors and features; and the presence of some probability of escape, survival, and rescue (however remote!).

Since an astronautic crew will probably consist of adult or mature individuals, the problem of dealing with sexual desires or impulses should not be overlooked as a possible source of psychological conflict. Just what would happen on a rather extended trip for males removed from their marital or romantic partners? We might first point to personnel in religious orders who commit themselves to voluntary abstinence or to convicts undergoing enforced abstinence from any normal sexual gratification. We also know that most physical or mental stresses tend to inhibit sexual impulses or desires in man. But, we have also heard of many schemes to occupy the romantic leisure time of male spacecrew members. Mixing the crew or sending along married couples would probably create more problems than it would solve, if we can judge from earthbound behavior.

Rather than relying upon such all-or-none measures in attempting to take care of this potential source of difficulty in the space vehicle, perhaps drugs could be applied when needed and to the degree deemed necessary for sexual control. Of course, this would probably necessitate the presence of a medically qualified individual to determine dosages and any contra-indications to the drugs.

A psychiatrist, in view of the possibility of other psychological problems arising, might be a logical addition to the spacecrew to administer these and other pharmacologic aids to the mental well-being of the crew. He could also provide medical care of the crew in case of illness or accident, medical checkups, and other preventive medical care of the crew, and even certain research functions.

We can quickly say that adequate facilities are needed for physical exercise, mental stimulation, and conventional entertainment. But, as far as entertainment and recreation are concerned, of what kind and to what degree are such facilities actually needed? What would be the most economical and long-lasting recreational forms? Which would be the most beneficial psychologically, while adequately reflecting all the individual likes and dislikes of the crew? The very presence of a multi-man crew might provide a rich storehouse of personal experiences which could be entertaining in the right social atmosphere. This type of social interaction also provides an opportunity for the individual reality testing and consensual validation so necessary to reduce crew vulnerability to self-generating emotional stress. The schematic on page 31 shows an internal closed loop of the man subsystem to emphasize the circularity in generation of emotional stress.

Insofar as physical exercise is concerned, we might ask what the optimum balance might be between the increased need for compensatory bodily movement and the requirement to minimize oxygen and food uptake. Under stress conditions, what will be the relationship between physical exercise and nutrition where the food may not be appealing nor the water particularly palatable?

Perhaps, despite all precautions and recreational opportunities, some difficulties may well occur. If this might be so, then we should also extend our thinking concerning recreation to the possible requirements for rehabilitation of spacecrews after they return. Interlude facilities were found to be quite necessary for repatriated American PW's during the Korean conflict. So our questions, generally, involve the interactions of many variables not only during the space-travel or space-residence phase directly, but also during preflight training and postflight rehabilitation.

Psychology a Concern

An analysis of presently available information regarding the psychological hazards of extended spaceflight indicates that this should be an area of grave concern to those planning manned space missions. It is apparent that psychological problems of surprising severity and incapacitating effect are likely to occur among the members of an unselected astronautic crew under the anticipated cumulative multiple-stress conditions of spaceflight. Greater attention and more intensive study is warranted of the problems of selection, training, and psychological environment of astronautic crew members. It seems particularly important to insure that sufficient, timely, and appropriate research be conducted to determine the relative importance of the various psychological factors and to find means to overcome or to compensate for any such undue hazards to the success of costly manned space ventures.

The 42 references of this discussion may be obtained by writing to the Editor. ◆◆

The Trouble with Space . . .

A recent AP dispatch helped to point up one of the reasons the U.S. space program is running into difficulties. The dispatch noted that Sen. Kenneth B. Keating (R., N.Y.) had recently received a letter from a young lady in Syracuse, N.Y., protesting about the nation's Man-in-Space program.

"I don't approve of sending our men up into space," she wrote. "They may stay up there and we'll end up by having more old maids here than ever."

Russian Optical Journal Available in Translation

The Optical Society of America is now translating and publishing the Russian Journal "Optika i Spektroscopiya" under an NSF grant. The translated journal is being distributed free to members of the Society and is also available to nonmembers in a package deal with the Society's journal at $25 a year. Additional details may be obtained by writing to the Society's executive offices at 1155 16th St. N.W., Washington 6, D.C.

Eighth International Combustion Symposium

The Symposium, organized under the auspices of the Combustion Institute, will be held at the California Institute of Technology between August 29 and September 2. Proposed papers, or abstracts of them, should be sent to Dr. S. S. Penner, Symposium chairman, at CIT.

People in the News

(CONTINUED FROM PAGE 83)

A. Clyde Flackbert has been appointed manager of administration for Tactical Weapon Systems operations at Ford's Aeronutronic Div.

Gerald Dennis becomes general manager of the new General Kinetics Corp., Burbank, Calif., a division of Hydra Electric Corp. **Oscar L. Wadkins**, research engineer and designer, becomes director of engineering.

Charles W. Creaser Jr. has been elected president of the newly formed Antenna Systems, Inc., at Hingham, Mass. **Walter W. VanderWolk Jr.** is executive vice-president.

At Washington Technological Associates, **Harold A. Timken Jr.** has been named assistant to the president, and will continue as assistant secretary of the company. **Richard E. Nearman** has been upped to chief engineer.

Jennings David, formerly director of engineering, has been appointed vice-president, engineering, Summers Gyroscope Co.

Morgan E. McMahon has been appointed manager and **Elmo E. Maiden,** assistant manager, respectively, of the Engineering Dept. at Pacific Semiconductors, Inc.

Matthew L. Devine has been elected president of Amphenol-Borg Electronics Corp.

William S. Schueler will head the design engineering group in the Research and Engineering Div. of Data-Control Systems, Inc.

James R. Lincicome has been appointed to the new post of manager of program planning for Motorola's Chicago Military Electronics Center. **Robert J. Gnaedinger Jr.** has been named senior solid state chemist for the Semiconductor Products Div.

Choh-Yi Ang has been named director of material laboratories, P. R. Mallory & Co., Inc.

Hazeltine Research Corp. has appointed **William F. Bailey, Richard J. Farber,** and **Donald Richman** associate directors of research.

Myron B. Baldwin, manager, Missile Products Div.; **Joseph R. Greer,** manager, Instrument Div.; and **Thomas E. Holland,** director, R&D Div., have been made vice-presidents at Beckman & Whitley, Inc.

HONORS

ARS members honored with 1959 IAS Annual Awards include: **James A. Van Allen,** ARS Fellow and 1949 C. N. Hickman Award winner, who received the IAS Hill Space Award for discovery of the Van Allen radiation belts; **Brig. Gen. Don D. Flickinger,** the John Jeffries Award "for outstanding contribution to the advancement of aeronautics through medical research"; and **Karel J. Bossart,** ARS Fellow and 1959 James H. Wyld Memorial Award winner, the Sylvanus Albert Reed Award for achievement in aeronautics.

Five ARS members became IAS Fellows. They are **Joseph V. Charyk,** Under Secretary of the Air Force; **Alfred Eggers Jr.,** NASA Ames Research Center; **Vice-Admiral John T. Hayward,** deputy chief of naval operations (development); **Lester Lees,** ARS Fellow, CalTech Guggenheim Aeronautical Lab; and **Lysle A. Wood,** vice-president, Boeing, and general manager of its Aero-Space Div.

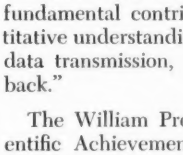
Sir George Edwards, managing director of Vickers-Armstrongs (Aircraft) Ltd., was the 1959 recipient of the Daniel Guggenheim Medal for notable achievements in the advancement of aeronautics.

Harry Nyquist, staff scientist in W. L. Maxson Corp.'s R&D Div., received the 1960 IRE Medal of Honor "for fundamental contributions to a quantitative understanding of thermal noise, data transmission, and negative feedback."

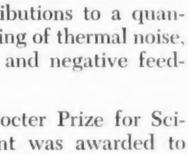
The William Procter Prize for Scientific Achievement was awarded to **Charles S. Draper** of MIT, in recognition of notable accomplishment in scientific research.

Hilliard W. Paige, general manager of GE's Missile and Space Vehicles Dept., and an ARS member, has been named Philadelphia area's "Engineer of the Year" for 1960 at the National Engineers' Week sponsored by the professional engineering societies.

The U.S. Junior Chamber of Commerce has designated **Peter A. Castruccio,** technical director of the Aerospace Div. of Aeronca Mfg. Corp., and an ARS member, as one of the outstanding young men of 1959. ♦♦



Paige



Castruccio

International Scene

(CONTINUED FROM PAGE 18)

suborbital and orbital, respectively, constitute a division into two policy-wise and jurisdictionally distinguishable classes, (a) the first of which (suborbital) overwhelmingly includes uses which bear a direct relation to the security and other vital interests of states beneath flightpath and should remain or be placed, therefore, under the exclusive regulatory authority of such subjacent states, and (b) the second of which (orbital) includes for the most part uses which only indirectly or casually affect the security and other vital interests of states beneath the flightpath, so that such states could afford to share regulatory jurisdiction thereover, i.e., delegate it to an international control authority."

To this question Dr. Sänger responded: "In the present, technically primeval, initial state of astronautic development, I think such a distinction possible, although it would rather soon be made obsolete, the future technical goal of aeronautical and astronautical engineering being the complete spatial independence of their vehicles. For these reasons, I deem a limitation in altitude of the national sovereign air space, analogously to the offshore limitations of maritime law to be more efficient for duration than a limitation of national sovereignty to certain categories of vehicles."

Dr. Sänger concludes, "The classification of aircraft and immediately returning spacecraft under national control, and of spacecraft not immediately returning to the planetary surface under international control, as suggested by you, would—with the appearance of continuous rocket propulsion engines—have to be supplemented by one category covering vehicles usable as aircraft and as spacecraft alike, and which do not follow preset trajectories, thus eluding your criteria. As the appearance of such vehicles may be expected much earlier than the disappearance of national empires, the altitude limits of sovereignty would have again to be taken recourse to. An arbitrary classification, namely, of these thoroughly universal vehicles under a definite category to be treated legally one way or the other, would not seem propitious. This example shows the general difficulty of pinning the criteria for national or international legal treatment to the vehicles, which are subjected to considerable fluctuation and development, instead of to the relatively stable national empires." ♦♦

Contract awards

Minuteman's Second Stage To be Produced by Aerojet

The Air Force has chosen Aerojet-General to produce the second stage for the Minuteman, with the contract subject to successful tests of Aerojet's second-stage hardware. Thiokol Chemical is building the first stage; Aerojet and Hercules Powder are working on plans for the third stage.

ASW Systems Contract

Texas Instruments Apparatus Div. has been awarded a $4.5 million contract by the Bureau of Naval Weapons for production of an advanced antisubmarine warfare system with delivery to begin in 1961. From Convair-Astronautics, TI received two contracts to develop and produce 24 telemetry systems for Centaur; from Boeing, a contract for production of 37 telemetry systems for the Bomarc C-2.

NASA Award to Avion

A "quick reaction" contract to provide engineering, laboratory, and model shop work associated with printed circuit electronics has been awarded to the Avion Div. of ACF Industries by NASA's Goddard Space Flight Center.

AEC R&D Awards

The AEC has awarded R&D contracts on uses of radioisotopes and radiation to: William H. Johnston Laboratories, Inc., (Lafayette, Ind.), $84,600, to continue basic studies in radiation technology including use of the coincidence mass spectrometer for the study of multiple ionization processes; Battelle Memorial Institute, $49,600, to continue R&D on principles of use of radioisotope tracer systems for process and quality control; Jarrell-Ash Co., $32,600, to determine the feasibility of utilizing beta rays from radioisotopes to generate x-rays suitable for fluorescent spectroscopy; and Bureau of Mines, to explore use of radioisotope tracers for fluid-dynamic studies.

$7.5 Million for Drones

Radioplane Div. of Northrop Corp. has received authorization from Army Ordnance to proceed on a $7,500,000 production contract of 400 RP-76 rocket-powered target missiles, including broad flight services.

Mercury Altitude Sensor

McDonnell Aircraft has awarded a $175,000 contract to Donner Scientific Co., Concord, Calif., for production of a maximum altitude sensor and accelerometers and accelerometer switches for Project Mercury. The maximum altitude sensor goes into action if it should become necessary to abort the rocket flight before the Astronaut's escape tower is jettisoned.

Equipment for Titan Bases

Contracts totaling more than $3,000,000 for operational propellant-loading systems and alarm-system equipment at four Titan bases have been awarded to CompuDyne Corp. by AFBMD and the Army Corps of Engineers. The systems will be installed at Ellsworth AFB, Rapid City, S. Dak.; Mather AFB, Sacramento; Mt. Home AFB, Idaho; and Larson AFB, Washington.

Hawk, Polaris Contracts

Raytheon will supply Hawk field maintenance equipment to the Boston Ordnance District under a $2,350,214 contract, and provide Polaris guidance components and industrial support to MIT's Instrumentation Lab under a $520,000 contract from the Navy Special Projects Office.

Switching Device

Electronic Systems Development Corp., subsidiary of Solar Aircraft, has received an AF contract for evaluation of an electronic static commutator which is said to consecutively open and close 60 different channels between sensing devices in a missile and the missile's radio transmitter.

Data Reduction Facility

A $381,000 contract from the Army Signal Corps to Beckman Instruments Systems Div. calls for development of a high-speed data reduction facility for the Army's Electronic Proving Ground, Ft. Huachuca, Ariz.

Navigation Systems

GPL Div. of General Precision has received a $3,700,000 contract from AMC's Aeronautical Systems Center for airborne navigation systems, including further procurement of components.

B-58 Checkout System

Additional funding of more than $1,300,000 for the defensive electronic countermeasures "checkout" system for the AF's B-58 has been received by ITT Corp.

Air Data Probes

Waste King Corp. has been awarded AF production contracts totaling about $250,000 for manufacture of air data probes.

Talos Telemetry Equipment

Allen B. Du Mont Laboratories will produce telemetry equipment and as-

NASA CONTRACTS FOR NOVEMBER

Contractor	Obligation	Program
Army Ordnance Corps	$480,000	Purchase of Castor solid rockets.
Brookings Institute	$100,000	Study of long-term social, technological, economic, political, and international implications of space exploration.
MIT	$ 50,000	Study of navigational equipment for use in circumlunar and planetary flights.
NBS	$100,000	Provide tables plotting electron densities at various altitudes from data of space experiments.
National Research Corp.	$110,000	Deliver ultrahigh vacuum system and prototype of extremely low-pressure detector to measure atmospheric pressures at high altitudes with sounding rockets.
Northrop Aircraft	$260,000	Airborne pressure devices for X-15.
Smithsonian Astrophysical Laboratory	$200,000	Design and build ultraviolet space survey instrumentation.
U. S. Weather Bureau	$ 50,000	Installation of five temporary receiving stations to record telemetry from Explorer VII launched Oct. 13, 1959.

sociated test equipment for the Talos under a $1,600,000 subcontract from Bendix Products Div.—Missiles.

Mace Theodolites

Contracts totaling $2,000,000 for production of alignment theodolites for the Mace missile have been received by Perkin-Elmer Corp. from GM's AC Spark Plug Div.

SYNOPSIS OF AWARDS

The following synopsis of government contract awards lists formally advertised and negotiated unclassified contracts in excess of $25,000 for each Air Force, Army, NASA, and Navy Contracting Office:

AIR FORCE

AFCRC, Laurence G. Hanscom Field, Bedford, Mass.

Investigation of the outer ionosphere by observation of extraterrestrial low-frequency radio noise in space vehicles, $30,785, **Harvard College,** 10 Divinity Ave., Cambridge, Mass.

Study of magnetohydrodynamics with application to phenomena occurring in the vicinity of our planet and in space, $39,831, **New York Univ.,** Washington Square, New York, N.Y.

Research on theory of feedback communication systems, $69,919, **New York Univ.,** University Heights, New York, N.Y.

Development of high altitude scanning radiometers, $128,893, **Ball Brothers Research Corp.,** Boulder Industrial Park, Boulder, Colo.

Research directed toward study and analysis on the radiative properties of plasmas including the effects of heavy ions, $43,500, **Univ. of Michigan,** Ann Arbor, Mich.

AFMTC, Patrick AFB, Fla.

Increase in funds, $85,205, **Motorola, Inc.,** 8201 E. McDowell Rd., Scottsdale, Ariz.

Increase in funds, $75,195, **Convair-Astronautics,** P.O. Box 1128, San Diego 12, Calif.

Increase in funds, $53,513, **Dynatronics, Inc.,** P.O. Box 2566, Orlando, Fla.

AFOSR, ARDC, Washington 25, D.C.

Research on boundary layers in high temperature gas flows, $48,576, **Cornell Aeronautical Laboratory, Inc.,** 4455 Genesee St., Buffalo 21, N.Y.

Research on molecular interactions at high temperature, $98,957, **Cornell Aeronautical Laboratory, Inc.,** 4455 Genesee St., Buffalo 21, .NY.

Continuation of research on effects of very high pressure and temperature on semiconducting and insulating materials, $77,500, **Battelle Memorial Institute, Columbus, Ohio.**

Research on vibrational and vibration-rotational spectroscopy, $26,000, **Univ. of Washington,** Seattle 5, Wash.

Research on high intensity plasma jets, $85,498, **Plasmadyne Corp.,** 3839 South Main St., Santa Ana, Calif.

Psychophysiological mechanisms of stress, $40,049, **Duke Univ.,** Durham, N.C.

Boundary layers in high-temperature gas flows, **Cornell Aeronautical Lab., Inc.,** Buffalo, N.Y.

Nonequilibrium flows, $52,120, **Cornell Aeronautical Lab., Inc.,** Buffalo, N.Y.

Molecular interactions at high temperatures, $98,957, **Cornell Aeronautical Lab., Inc.,** Buffalo, N.Y.

Ultra-energy fuels for rocket propulsion, $70,852, **Aerojet-General,** Azusa, Calif.

Chemical kinetics at high temperatures, $33,000, **Univ. of Calif.,** Los Angeles, Calif.

Mechanical properties of intermetallics, $32,530, **Yale Univ.,** New Haven, Conn.

Ogden Air Materiel Area, Hill AFB, Utah.

Data in support of IM99A missile, $39,600, **Boeing Airplane Co.,** Pilotless Aircraft Div., P.O. Box 3925, Seattle 24, Wash.

Data in support of SM62A missile, $29,800, **Northrop Corp.,** Norair Div., Hawthorne, Calif.

ARMY

ARMY Ordnance Dist., Birmingham, 2120 Seventh Ave., N., Birmingham 3, Ala.

Research and developmental study of shielding problems in manned space vehicles, $49,000, **Lockheed Aircraft,** Georgia Div., Marietta, Ga.

Engineering and design services, ground support equipment, Saturn, supplement, $390,000, **Hayes Aircraft Corp.,** P.O. Box 2287, Birmingham, Ala.

Pershing weapon system, $10,500,000, **The Martin Co., P.O. Box 5837, Orlando,** Fla.

Enginering services for LaCrosse Missile system, $951,001, **The Martin Co.,** Sand Lake Road, Orlando, Fla.

Basic research pertaining to telemetering, measuring, and radio frequency systems, supplement, $50,000, **Auburn Research Foundation, Inc.,** Alabama Polytechnic Institute, Auburn, Ala.

Army Ordnance Dist., Los Angeles, 55 S. Grand Ave., Pasadena, Calif.

Motors for 115MM boosted rocket, $120,168, **Norris-Thermador Corp.,** 5215 S. Boyle Ave., Vernon, Calif.

Guided missile research and development, $135,000, **CalTech,** 1201 E. California St., Pasadena, Calif.

Rocket engines, $150,000; design and development of NAA H-1 motors, $28,-500, **North American Aviation,** 6633 Canoga Ave., Canoga Park, Calif.

Design and structural analysis, $324,-162, **North American Aviation Inc.,** 12214 Lakewood Blvd., Downey, Calif.

Tunnel development, $86,662, **Plasmadyne Corp.,** 3839 S. Main St., Santa Ana, Calif.

Research and development effort on the Sergeant missile system, $2,491,644, **Sperry Rand Corp.,** 322 N. 21st West, Salt Lake City, Utah.

Army Ordnance Dist., Philadelphia, 128 N. Broad St., Philadelphia 2, Pa.

Research and development on electron density distribution in semiconductors $25,500, **Univ. of Pittsburgh,** Pittsburgh 13, Pa.

Test for aerodynamic heating, $44,378, **Research Institute of Temple Univ.,** 4150 Henry Ave., Philadelphia 44, Pa.

Army Signal Supply Agency, 225 S. 18th St., Philadelphia 3, Pa.

Solid propellant rocket motors, $43,-897, **Rocket Power Div. of Gabriel Co.,** Mesa, Ariz.

Research work for 12 months on utilization of self-sustained electron emission, $100,000, **Tung-Sol Electric, Inc.,** Newark, N.J.

Services and materials for one primary and two secondary satellite tracking stations, $300,000, **Collins Radio Co.,** Dallas, Tex.

Ground stations for courier communication satellite system, $200,000, **ITT Labs,** Nutley, N.J.

Boston Ordnance Dist., Army Base, Boston, Mass.

Detail technical scope of first phase demonstration of thrust, $49,468, **Goodrich Voltage Astronautics, Inc.,** Burlington, Mass.

Design and development, integrated airborne PCM telemetry system, $60,772, **RCA,** Burlington, Mass.

NY Ordnance Dist., 770 Broadway, New York 3, N.Y.

Analysis of radar noise in the Nike and related systems, $100,000, **Columbia Univ.,** Box 6, Low Memorial Library, Broadway at 116th St., New York 27, N.Y.

NASA

Langley Research Center, Langley AFB, Va.

Telemetering equipment, $42,166, **Panoramic Radio Products, Inc.,** 520 S. Fulton St., Mt. Vernon, N.Y.

Lewis Research Center, 21000 Brookpark Rd., Cleveland 35, Ohio.

Spectrograph and auxiliary equipment for Lewis Research Center, $30,516, **Parrell-Ash Co.,** 26 Farwell St., Newtonville 60, Mass.

Pressure transducers for Lewis Research Center, $40,600, **Statham Instrument,** 12401 West Olympic Blvd., Los Angeles 65, Calif.

Magnetic tape recording system for Lewis Research Center, $47,533, **Ampex Corp.,** 528 Vinewood Ave., Birmingham, Mich.

NAVY

Bureau of Ships, Washington, D.C.

Develop and evaluate an ultrahigh temperature dielectric liquid material for potting of electronic components, $45,-176, **Monsanto Chemical Co.,** Everett Station, Boston, Mass.

Atmosphere analyzer, $196,985, **Beckman Instruments, Inc.,** 2500 Fullerton Rd., Fullerton, Calif.

Naval Training Device Center, Pt. Washington, N.Y.

Psychological study of spaceflight training, biomechanics of spaceflight, project 0-4006, $39,631, **Operations Research, Inc.,** Silver Spring, Md. ♦♦

WROUGHT PRECIPITATION-HARDENING STAINLESS STEELS

Compiled by C. P. King

Materials and Process Section
Marquardt Co., Van Nuys, Calif.

CHEMICAL ANALYSIS (%)

MATERIAL	C	Mn	P	S	Si	Cr	Ni	Mo	Al	N	Fe
17-7PH	0.09 MAX	1.00 MAX	0.04 MAX	0.04 MAX	1.00 MAX	16.00 to 18.00	6.50 to 7.75		0.75 to 1.50		BAL
PH15-7Mo	0.09 MAX	1.00 MAX	0.04 MAX	0.04 MAX	1.00 MAX	14.00 to 16.00	6.50 to 7.75	2.00 to 3.00	0.75 to 1.50		BAL
17-4PH	0.07 MAX	1.00 MAX	0.04 MAX	0.03 MAX	1.00 MAX	15.50 to 17.50	3.00 to 5.00	Cu 3.00 to 5.00	Cb + Ta 0.25 to 0.45		BAL
AM350	0.08 to 0.12	0.50 to 1.25	0.04 MAX	0.03 MAX	0.50 MAX	16.00 to 17.00	4.00 to 5.00	2.50 to 3.25		0.07 to 0.13	BAL
AM355	0.10 to 0.15	0.50 to 1.25	0.04 MAX	0.03 MAX	0.50 MAX	15.00 to 16.00	4.00 to 5.00	2.50 to 3.25		0.07 to 0.13	BAL

The precipitation-hardening grades of stainless steel have found wide application in the aircraft and missile fields because of their excellent combination of (1) high strength, (2) corrosion resistance, and (3) relative ease of fabrication.

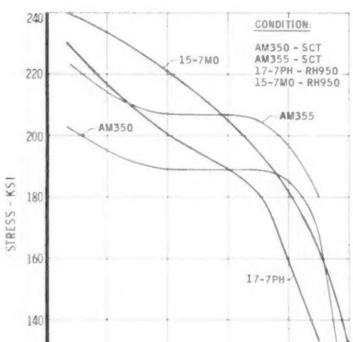
Two types are represented. The martensitic alloys, typified by 17–4 PH, are available as bar, rod, wire, and forging. The semiaustenitic alloys, represented by 17–7 PH, PH 15–7 Mo, AM 350, and AM 355 are available as sheet, plate, strip, bar, rod, wire, and forging.

All these alloys may be produced from conventional steel mill equipment and by standard melting and casting procedures.

Fabrication

All of these alloys may be machined easily and at high speeds. In sheet form, 17–7, 15–7, AM 350, and AM 355 are formable by conventional techniques, although they workharden rapidly and severe forming operations require intermediate anneals. It is possible to form these alloys in soft annealed conditions, then harden by comparatively low-temperature heat treatment.

ULTIMATE TENSILE STRENGTH OF PRECIPITATION-HARDENING STAINLESS STEELS



SHORT TIME ROOM TEMPERATURE PROPERTIES

	CONDITION		YS (psi)	UTS (psi)	ELONGATION(%)
17-7PH	TH 1050	MINIMUM	150,000	180,000	4-7*
		TYPICAL	185,000	200,000	9
	RH 950	MINIMUM	180,000	200,000	2-6*
		TYPICAL	195,000	215,000	9
PH15-7Mo	TH 1050	MINIMUM	170,000	190,000	3-5*
		TYPICAL	200,000	210,000	7
	RH 950	MINIMUM	200,000	225,000	2-4*
		TYPICAL	215,000	240,000	6
17-4PH	H 900	MINIMUM	165,000	180,000	8
		TYPICAL	180,000	195,000	13
AM350	SCT	MINIMUM	150,000	185 000	10
		TYPICAL	170,000	200 000	13
AM355	SCT	MINIMUM	165,000	190,000	10
		TYPICAL	185,000	215,000	12

* MINIMUM VALUES WILL VARY WITH GAGE

Joining

PH 15–7 Mo is the most difficult to weld, being subject to hot-cracking and embrittlement. The other alloys are weldable by the same methods used for the standard grades of stainless steel and have a joint strength over 90 percent that of the base metal. Brazing is particularly applicable to these materials and is best used when the brazing operation can be combined with annealing. Honeycomb structures have made wide use of 17–7, both resistance welded and brazed.

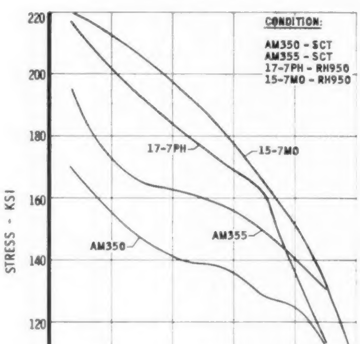
PHYSICAL PROPERTIES OF THE PRECIPITATION-HARDENING STAINLESS STEELS

	MATERIAL			
	17-7PH PH15-7Mo		17-4PH	AM-350 AM-355
	Condition RH950	Condition TH1050	Condition H900	Condition SCT
Density lbs. per cu. in.	0.276	0.276	0.282	0.286
Coefficient of Thermal Expansion 10^{-6} in./in./F				
70-400F	6.0	5.8	6.1	7.0
70-800F	6.2	6.1	6.5	7.0

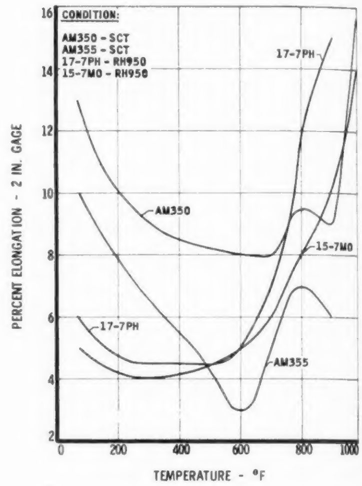
Applications

Components such as skins, ribs, levers, springs, hinges, clamp rings, and pressure vessels have been made from the precipitation-hardening stainless steels.

YIELD STRENGTH OF PRECIPITATION-HARDENING STAINLESS STEELS



PERCENT ELONGATION OF PRECIPITATION HARDENING STAINLESS STEELS



Other Alloys

Several other alloys have been developed which belong in this category. These include 17–10P, 785, 17–14 Cu-Mo, HNM, 16–6V, 17–7V, and Stainless W; but none of these has yet found wide application.

Physical Properties

A typical Cr-Mo-V die steel has a density of 0.280 lb/in.^{3} and coefficient of thermal expansion (unit, 10^{-6} in./in./F) of 6.5 between 80 and 400 F, 7.1 between 80 and 800 F, and 7.4 between 80 and 1200 F.

Heat Treatment

These steels are preheated to 1400–1500 F and hardened at 1800–1900 F. Exact conditions vary with steel type. All three are air-quenched and tempered at 1000–1100 F; H-12 can also be oil-quenched.

HEAT TREATMENT

17-7PH
PH15-7Mo

ANNEAL 1950 ± 25°F

RH 950

1750 ± 15°F FOR 10 MIN.
AIR COOL TO RT
COOL TO -100 ± 10°F
HOLD FOR 8 HOURS
950 ± 10°F FOR 1 HOUR
AIR COOL

TH 1050

1400 ± 25°F
AIR COOL TO 60°F WITHIN 1 HOUR
HOLD 30 MIN.
1050 ± 10°F FOR 90 MIN.
AIR COOL

17-4PH

ANNEAL 1900 ± 25°F

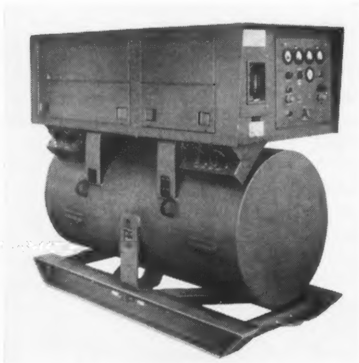
H 900
900 ± 25°F FOR 1 HOUR

AM350
AM355

SCT

1710 ± 25°F FOR 30 MIN.
COOL TO -100 ± 10°F
HOLD FOR 3 HOURS
TEMP. AT 850°F FOR 3 HOURS

New equipment and processes

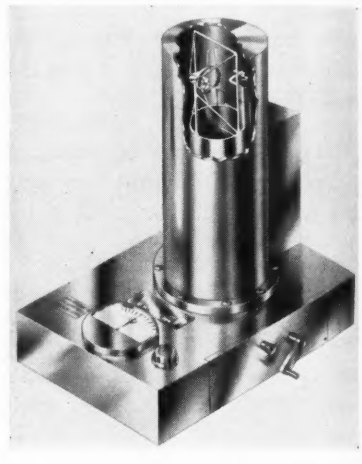


Missile Power Supply: Built for Nike-Hercules, this 400-cycle motor-generator set has been field-tested at White Sands, N.M. A saddle-mounted enclosure atop the set contains all starting, protective, and switching equipment. Input and output plugs and complete metering are provided. Rating, 60 kw at 1200 rpm. Electric Machinery Mfg. Co., Minneapolis, Minn.

Portable X-Ray Unit: Penetration capability of 4-in. steel, 300-kv power, and a carrying weight of 150 lb are combined in the Baltograph 300. The X-ray head is cylindrically shaped, measuring 46 in. long by 12 in. in diam. Incorporated in the head are the tube, lead shield, HT transformer, filament heating transformer, automatic thermal cutoff, and receptacle for the control panel connector cable. Balteau Electric Corp., Stamford, Conn.

Jet Fuel Tester: An accurate, quick, and inexpensive means of estimating the amount of foreign material in jet fuel has been developed in the form of a simple "black box." The device excludes all light except for a flashlight beam passing through a window on one side. Particles in concentrations as low as one part in 10 million can be detected. The Pure Oil Co., 35 E. Wacker Dr., Chicago 1, Ill.

Fused-Quartz Pressure Gauge: Available in four pressure (H_3) ranges–0 to 1, 0 to 40, 0 to 80, and 0 to 120–all and repeatable to within 1 part in



30,000, this gauge can reproduce pressures to the same degree of accuracy 1 min or 10 days from the initial reading. Its fused-quartz mechanism gives it low hysteresis. Buck Instrument Co., P. O. Box 357, Boulder, Colo.

VHF Pulse Transmitter: Peak pulse power of 100 watts is delivered at a maximum duty cycle of 50 percent into a nominal load impedance of 50 ohms by the model 200A transmitter. Input modulation requirement is 1 to 4 v peak into a 100-ohm termination. RF output signal between modulation pulses is 50 db or more below the 1 kw output signal. Unit operates from a 208 v, 60-cycle, 3-phase, 4-wire input. Sierra Electronic Corp., 3885 Bohannon Dr., Menlo Park, Calif.

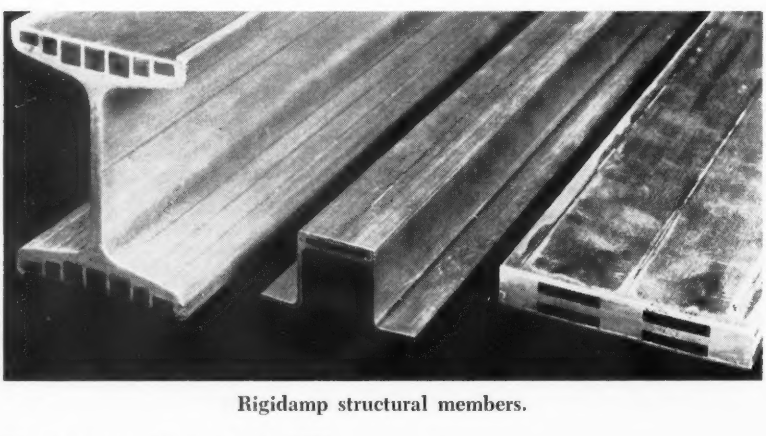
Pressure Transducer: A flush-mounted transducer, Type 4-327, is obtainable in pressure ranges from 0 to 100 and 0 to 5000 psi gauge and absolute. The pressure sensitive diaphragm can measure high-frequency transient phenomena. Provision is made for adjustment of bridge balance, temperature compensation, and sensitivity external to the unbonded strain gauge sensing element. Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif.

Rigidamp–Built-in Vibration Damping

Structural members incorporating a viscoelastic material in laminar or cellular form can substantially reduce resonant vibration. This is the story of Rigidamp, the trademark Barry Controls Inc., Watertown, Mass., has given its practical applications of the theory of optimum damping developed by engineers J. E. Ruzicka and R. D. Cavanaugh of the company.

This method of damping promises to ameliorate many of the problems of fatigue and stress associated with vibrations produced by powerful rocket and jet engines. Rigidamp structures can be made as sheet and thin beams with laminar damping layers and as I-beams, channels, and angles with cellular damping. The use of the technique imposes some penalties in strength loss and weight gain, as compared with conventional structures. But, because many designs are based on dynamic-stress levels, Rigidamp structures may possibly not sustain these penalties in many applications.

Obvious possible applications of Rigidamp structures are missile skins, test fixtures, electronic equipment frames, mounting bases, etc. Most research to date by Barry has been on metal structures, but the company has applied the technique successfully to plastics as well.



Rigidamp structural members.

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